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NATIVE FRUIT DEVELOPMENT PROGRAM - INTEGRATED PEST MANAGEMENT, YIELD DETERMINATION, AND IMPROVED PROPAGATION TECHNOLOGY FOR SASKATOONS

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Native Fruit Development Program (NFDP) – SRP Transition

Prepared by

Richard St-Pierre
Research Scientist
Department of Plant Sciences
University of Saskatchewan, Saskatoon

March 31, 2004

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20030466

Native Fruit Development Program: SRP Transition

ADF Project #20030187

Final Report – March 31, 2004

Richard St-Pierre, Ph.D.
Research Scientist
Department of Plant Sciences
University of Saskatchewan
Saskatoon

1. ABSTRACT/SUMMARY

Project Deliverables were to include: 1) a final report on the Native Fruit Program's core activities; 2) final or progress reports for three competitive ADF projects; 3) preparation of scientific manuscripts of the results of recently-completed projects; and 4) preparation of extension summaries for the Prairie Fruit Journal. Project Results have included reports on: 1) a multi-factorial experiment on the effects of cultivar, explant juvenility, multiplication cycle & etiolation in culture on rooting of micro-propagated saskatoons; 2) screening of saskatoon accessions for resistance to Entomosporium leaf and berry spot; 3) saskatoon and other native fruit cultivar trials; 4) effect of soil mulch and planting date on the survival and field establishment of saskatoon transplants; 5) impact of heading-back dormant saskatoon plants during orchard establishment; and 6) effects of propagation method and cultivar on transplant survival and growth. Project results also have included: 7) the continued distribution of native fruit manuals; 8) the provision of problem-solving and diagnostic services to requests from fruit growers; 9) provision of the HTML code and files for the Native Fruit Development Program's website; 10) identification of research gaps needed to further the development of the native fruit industry in Saskatchewan; 11) an inventory of experimental sites and materials, including field plans/layouts; 12) final or progress reports for three competitive ADF projects (19990317 - model to forecast Entomosporium, 20000232 - IPM strategy for control of Entomosporium leaf and berry spot, and 20020069 - Screening of insecticides); 13) the completion of four scientific manuscripts; and 14) the completion of seven extension summaries for the Prairie Fruit Journal.

2. EXECUTIVE SUMMARY

Project objectives, as per the Addendum to Appendix A of the Project Contract, were: 1) To develop up-to-date documentation in the form of Final and/or Progress Reports of the various research activities and projects undertaken by the Native Fruit Development SRP; 2) To prepare scientific manuscripts, and to submit these to peer-reviewed journals in an effort to make project results available to the larger scientific community; and 3) To develop updated extension materials, and to make these available to SAFRR extension staff and Saskatchewan fruit growers.

Project Deliverables, as per the Addendum to Appendix A of the Project Contract, were to include: A Final Report on the Native Fruit Development Program's core activities - Activity-specific deliverables were to include reports on: 1) a multi-factorial experiment on the effects of cultivar, explant juvenility, multiplication cycle & etiolation in culture on rooting of micro-propagated saskatoons; 2) screening of saskatoon accessions for resistance to Entomosporium leaf and berry spot; 3) saskatoon and other native fruit cultivar trials; 4) effect of soil mulch and planting date on the survival and field establishment of saskatoon transplants; 5) impact of heading-back dormant saskatoon plants during orchard establishment; 6) effects of propagation method and cultivar on transplant survival and growth. Project deliverables were also to include: 7) the continued distribution of native fruit manuals; 8) the provision of problem-solving and diagnostic services to requests from fruit growers; 9) provision of the HTML code and files for the Native Fruit Development Program's website; 10) identification of research gaps needed to further the development of the native fruit industry in Saskatchewan; 11) an inventory of experimental sites and materials, including field plans/layouts; 12) final or progress reports for three competitive ADF projects (19990317 - model to forecast Entomosporium, 20000232 - IPM strategy for control of Entomosporium leaf and berry spot, and 20020069 - Screening of insecticides); 13) the completion of scientific manuscripts; and 14) the completion of extension summaries for the Prairie Fruit Journal.

Project Results:

1) Report on the effects of explant juvenility, *in vitro* etiolation and subculture number and length on *ex vitro* rooting of micropropagated saskatoons: Successful micro-propagation of saskatoons is limited by the problem of unsuccessful rooting. *In vitro* rooting has yielded erratic results and plants are difficult to establish in soil or an artificial medium. The objective of this study was to improve the rooting of micro-propagated saskatoons by using an *ex vitro* method. The effects of explant juvenility, *in vitro* etiolation and subculture number and length on *ex vitro* rooting were tested and possible mechanisms of these effects were examined.In general, the results of this study indicated that using explants from juvenile source tissues, applying etiolation *in vitro* and using more and longer subcultures would improve *ex vitro* rooting of micro-propagated saskatoons.

2) Report on screening of saskatoon accessions for resistance to Entomosporium leaf and berry spot: Entomosporium leaf and berry spot is a serious disease of saskatoon. Consequently, the development of saskatoon cultivars with durable disease resistance would provide a safer and more cost-effective way to control the disease. A detached leaf assay test identified a number of saskatoon genotypes that developed less leaf and berry spot infection than three of the currently grown cultivars. Further verification of the results of the screening needs to be done, followed by field trials of more mature plants. Extensive testing of these genotypes under field conditions is necessary. Although this material may be resistant to Entomosporium leaf and berry spot, the genotypes may not be agronomically suitable for commercial production and ultimately, would have to be incorporated into a breeding program. It should be noted that this study is incomplete due to the termination of the Native Fruit Program.

3) Reports on the saskatoon and other native fruit cultivar trials: This study enabled the

quantitative characterization and direct comparison of 15 mature saskatoon cultivars from replicated trials at two sites over five years. Previously, data from replicated trials was not available for mature plants of these cultivars. Such information is directly valuable to the grower. High yielding cultivars with good fruit size are important for the commercial production of saskatoons. An orchard of cultivars with different harvest times may be beneficial in extending the harvest period. Of the cultivars tested, those with high yields and a large fruit size included JB30, Thiessen and Martin. Pearson II, Honeywood, Smoky, Northline and Forestburg had high yields and medium-sized fruit. Pearson II, Honeywood and Smoky tended to have the highest fruit yields among these cultivars although not significantly different, but also had a greater tendency towards alternate bearing. Of these cultivars, JB30, Thiessen, Martin and Honeywood fruited earlier than Northline.

Of the chokecherry cultivars evaluated, the high yielding capacity of the selection, Espenant, warrants further attention. Garrington and Lee Red also proved to be more productive of the chokecherry cultivars. The large fruit size of Goertz makes this chokecherry cultivar attractive for both fresh consumption and processing. Of the pincherry cultivars evaluated, Lee #4 stood out as being very productive. The highbush cranberry cultivars, Garry Pink, Wentworth and Manitou produced good yields. Of these three, Manitou also had large fruit. Of the black currants cultivars evaluated, McGinnis Black, Ben Nevis, Wellington and the selection 5-23-42 were high yielding with large fruit. However, black currant production in Saskatchewan will probably always be highly variable producing inconsistent and often poor yields due to the unsuitable climate. Until the breeding and selection of black currant to produce cultivars that can better tolerate the prairie climate, commercial production of black currants in Saskatchewan may not be feasible. A number of the native fruit cultivars evaluated in this study proved to be superior in yielding capacity and/or fruit size. This information was not previously available and will provide a basis for cultivar selection of these fruits by growers.

4) Report on the effect of soil mulch and planting date on the survival and field establishment of saskatoon transplants: Little research has been done on the orchard management practices of the saskatoon. Knowledge of what factors influence the survival, successful establishment, growth and vigour of saskatoons is limited. Poor survival and establishment in the field is a frequent problem. The use of soil mulches has been reported to increase the growth and establishment of newly planted orchards and, in this study, the effect of black plastic and wood chip soil mulches on saskatoon plant growth and establishment in the field was examined. Additionally, young saskatoon plants are often received from many propagators as actively growing plants anytime between May to September, and therefore, the timing of transplanting of these non-dormant plants to the field can be crucial to ensure their optimum survival and establishment. In this study, five transplanting dates of non-dormant saskatoon plants were investigated for their effect on plant growth and survival. Transplant month had a great effect on the survival and establishment of non-dormant saskatoon transplants. In general, spring planting (late May until late June) resulted in the best survival and growth followed by that in September. Late June planting is not always advisable as the temperatures at this time of the year can often be similar to that of mid-summer. Therefore, transplanting into the field in late May to mid-June would be recommended. More research needs to be done to adequately discern the effects of both plastic and wood chip mulch on survival and growth of saskatoon transplants. It appears that plastic

mulch can be beneficial in enhancing plant growth, however, if plants are stressed, survival can be adversely affected. The use of plastic mulch combined with the spring planting of healthy plants may result in significantly greater growth without a decrease in plant survival. Although plants in wood chip mulch often exhibited a significantly greater survival than that in plastic, they did not exhibit an increase in growth. In addition, wood chip mulch appeared to be detrimental to sucker production and sucker growth. This may be a concern, particularly for cultivars that are not as profuse in suckering as Smoky. A thinner layer of the wood chip mulch may not have had the same negative effect on suckering. Plants in this study were actively growing when transplanted to the field. The planting of dormant plants may have yielded different results for both the effect of planting month and mulching.

5) Report on the impact of heading-back dormant saskatoon plants during orchard establishment: For a number of years, the pruning of saskatoon transplants at the time of orchard establishment has been promoted, in the absence of any published data, and in contradiction to the scientific literature which indicates that woody plants do not benefit from radical pruning at the time of transplanting. In general, pruning dwarfs plants and can have a negative effect on economic yields early in the establishment of an orchard because woody plants require a certain amount of growth before they flower and produce fruit. This trial was established to determine the impact of heading-back on the survival, growth and yield of three saskatoon cultivars. Differences between cultivars had a greater impact on the parameters measured during this study than either of the heading-back treatments that were applied. Transplant survival was unaffected by any of the cultivar or heading-back treatments. Two years after the first heading-back treatment was applied, a substantial reduction in plant size and branch number of the headed-back plants was observed. However, although the first heading-back treatment initially appeared to negatively impact some growth parameters, these effects were largely overcome by the end of the 2003 growing season. It seems that heading-back effects diminish as growing seasons pass since there was almost no differences found between plants that were headed-back during season two and those that were not headed-back at all. The second heading-back treatment resulted in reduced growth, an increase in plant height, and a slight increase in branching during the 2003 season. There is no evidence to date that these small treatment effects would have an impact on yield. Based on the results observed to date and considering the time and labour involved in conducting this practice, there is no reason to encourage growers to head-back their plants either in year 2 or year 4 of orchard establishment. It is important to note that this study is incomplete due to the termination of the Native Fruit Development Program. Two to four more years of data would be required to adequately assess the results of the experimental treatments applied in terms of yield in particular.

6) Report on the effects of propagation method and cultivar on transplant survival and growth: The objective of this trial was established to determine the impact of propagation method on transplant establishment, plant growth and yield of several saskatoon cultivars. Data collection in this trial was seriously compromised by poor quality micropropagated plant material and animal pest problems. These effects were mitigated to some extent by the fourth field season. Nevertheless, this field trial would require several more seasons in order to adequately measure the effects of propagation method on growth and yield. The data generally indicated that poor quality plant material, as obtained from the propagator, has a significant negative effect on plant

growth. The data also generally indicated that the effects of cultivar were greater than the effects of propagation method. It appears that growers who have planted seedling-propagated plants can expect a greater number of suckers and increased sucker growth. It is unclear at this point whether this would have any impact on yield, either positively or negatively, in the long-term. It is probable however that this difference in plant growth habit would increase the amount of labour needed to keep this growth in check. It is important to note that this study is incomplete due to the termination of the Native Fruit Development Program. Two to four more years of data would be required to adequately assess the results of the experimental treatments applied in terms of yield in particular.

7) Since the last Native Fruit Program Annual Report (December 2002), the Program has received 492 requests for information, and 46 saskatoon manuals, and 31 other manuals have been distributed. Problem-solving and diagnostic services were provided to the industry on request. Adequate resources were not available to create updated factsheets for the saskatoon manual, primarily because personnel were either let go, or left to take positions elsewhere due to the termination of the Native Fruit Program. The HTML code and files for the Native Fruit Development Program website are included on the CD containing the electronic version of this report.

8) In regards to the identification of research gaps needed to further the development of the native fruit industry in Saskatchewan, it has become apparent that information has been distributed that indicates that the Native Fruit Development Program has succeeded in completing all of the research that needs to be done in terms of saskatoon production. However, in contrast to this information, the reality of the situation is that it is obvious that a considerable amount of research remains to be done in a number of production related areas including: a) Determinants of yield (as greater average yields are critical to the economic success of the industry); b) Integrated pest management (as the saskatoon as a crop likely will run into critical long-term insect pest and disease problems without ongoing work in this area); and c) Fruit quality as it relates to environment, cultural practices, harvest and postharvest storage practices (as the quality of any processed product is dependent on the production system and how well this is integrated with the weather.)

9) The experimental designs for the studies conducted are described in the Materials and Methods of all applicable reports. Field plans/layouts for most studies were included. Field plans for the transplant study were not included as the study involved destructive harvests and therefore no longer exists. Approximately 150 pages of handwritten and typed germplasm inventories are contained in files left in the Department of Plant Sciences at the University of Saskatchewan.

10) Final or progress reports for three competitive ADF projects (19990317 - model to forecast Entomosporium, 20000232 - IPM strategy for control of Entomosporium leaf and berry spot, and 20020069 - Screening of insecticides) were submitted under separate cover.

11) Four scientific manuscripts were written and are in the process of being submitted to various scientific journals. These manuscripts include: a) Comparative Agronomic Performance of 15

Saskatoon (*Amelanchier alnifolia* Nutt.) Cultivars At Maturity; b) Fruit Quality Assessment of 16 Saskatoon (*Amelanchier alnifolia* Nutt.) Cultivars; c) Comparative Agronomic Performance of Cultivars of Choke Cherry (*Prunus virginiana* L.), Pin Cherry (*Prunus pensylvanica*), and Highbush Cranberry (*Viburnum trilobum* Marsh.), Grown in Saskatchewan; and d) Fruit Physicochemical Properties of Cultivars of Choke Cherry (*Prunus virginiana* L.), Highbush Cranberry (*Viburnum trilobum* Marsh.), and European Black Currant (*Ribes nigrum* L.) Grown in Saskatchewan.

12) Seven extension summaries were completed for the Prairie Fruit Journal: a) Comparative Agronomic Performance of 15 Saskatoon Cultivars At Maturity; b) The Agronomic Performance of Chokecherry, Pincherry, Highbush Cranberry and Black Currant Cultivars Evaluated in Saskatchewan; c) The Effect of Soil Mulch and Planting Date on the Survival and Field Establishment of Saskatoon Transplants ; d) A Note On The Impact of Heading-back Dormant Saskatoon Plants During Orchard Establishment; e) Physicochemical Properties of Fruit of 16 Saskatoon Cultivars; f) Physicochemical Properties of Fruit of Chokecherry, Highbush Cranberry, and Black Currant Cultivars Grown in Saskatchewan; and g) Effects Of Explant Juvenility, *In Vitro* Etiolation And Subculture Number And Length On *Ex Vitro* Rooting Of Micropropagated Saskatoons.

3. TECHNICAL REPORT

3.1. Background

Project objectives, as per the Addendum to Appendix A of the Project Contract, were: 1) To develop up-to-date documentation in the form of Final and/or Progress Reports of the various research activities and projects undertaken by the Native Fruit Development SRP; 2) To prepare scientific manuscripts, and to submit these to peer-reviewed journals in an effort to make project results available to the larger scientific community; and 3) To develop updated extension materials, and to make these available to SAFRR extension staff and Saskatchewan fruit growers.

Project Deliverables, as per the Addendum to Appendix A of the Project Contract, were to include:

1. A Final Report on the Native Fruit Development Program's core activities. Activity-specific deliverables will include the following:

Activity I: Development Of New Native Fruit Cultivars. The objectives of this activity are: a) to collect and characterize germplasm, and to select and propagate superior varieties of native fruit species; and b) to use traditional and contemporary breeding techniques to produce new native fruit cultivars with improved agronomic characteristics, fruit quality, and disease and insect pest resistance. Expected Results: A multi-factorial experiment (M.Sc. project) on the effects of cultivar, explant juvenility, multiplication cycle & etiolation in culture on rooting of micro-propagated saskatoons will be completed. Artificial screening of the accessions that may be resistant to *Entomosporium* will be completed (provided that conditions are conducive to the development of disease such that inoculum for screening can be obtained) and the final results reported on.

Activity II: Native Fruit Cultivar Evaluation Trials. The objective of this activity is to evaluate native fruit cultivars for agronomic characteristics. Expected Results: Final results (primarily yield data) for the saskatoon cultivar trials at the U of S and Moonlake, and the native fruit cultivar trials at the UofS, will be reported.

Activity III: Understanding Growth, Development & Yield Production In Native Fruit Species. The objective of this activity is to determine what factors influence the survival, successful establishment, and growth, vigour, volume and consistency of yield, and fruit quality of native fruit species so as to provide knowledge for the development of improved management practices. Expected Results: Final results for the transplant, pruning and propagation method projects will be reported.

Activity IV: Information Development And Distribution To The Fruit Industry. The objective of this activity is to develop, or revise, and distribute information to the fruit industry, and to provide problem-solving and diagnostic services for the industry. Expected Results: The 10 currently available manuals will continue to be distributed. Updated factsheets for the saskatoon manual may be completed, where possible, if resources permit. The HTML code and files for the Native Fruit Development Website will be made available to SAFRR for use on their website. Problem-solving and diagnostic services will be provided to the industry on request, provided that resources are available.

The Final Report will include the identification of research gaps needed to further the development of the native fruit industry in Saskatchewan, and an inventory of experimental sites and materials, including experimental designs and field plans/layouts.

2. Final or comprehensive Progress reports for each of the (competitive) ADF projects being undertaken by Dr. Richard St. Pierre. Current ADF projects include 19990317 (A model to forecast Entomosporium; this may include a workable web-based model, depending on remaining funds available, and lack of programming difficulties); 20000232 (IPM strategy for control of Entomosporium leaf and berry spot); and 20020069 (Screening of insecticides). In cases where a Final Report cannot be completed (e.g. one scheduled for 2006), a comprehensive progress report, including recommendations as to the advisability and usefulness of continuing the project, will be submitted.

3. Where data/results permit, scientific manuscripts of the results of recently-completed projects will be prepared and submitted to scientific journals (however, the publication process will be dependent on the results of peer review, and the availability of funding for publication).

4. Project results presented in the above reports and manuscripts will be summarized and made available to the industry and SAFRR extension personel via the Prairie Fruit Journal.

3.2. Final Report On The Native Fruit Development Program's Core Activities

3.2.1. Development Of New Native Fruit Cultivars

Objectives

The objectives of this activity were: a) to collect and characterize germplasm, and to select and propagate superior varieties of native fruit species; and b) to use traditional and contemporary breeding techniques to produce new native fruit cultivars with improved agronomic characteristics, fruit quality, and disease and insect pest resistance.

Deliverables

Deliverables for this activity were to include: a) A multi-factorial experiment (M.Sc. project) on the effects of cultivar, explant juvenility, multiplication cycle & etiolation in culture on rooting of micro-propagated saskatoons will be completed; and b) Artificial screening of the accessions that may be resistant to *Entomosporium* will be completed (provided that conditions are conducive to the development of disease such that inoculum for screening can be obtained) and the final results reported on.

Results

A report on the multi-factorial experiment (M.Sc. project) on the effects of cultivar, explant juvenility, multiplication cycle & etiolation in culture on rooting of micro-propagated saskatoons was completed and follows below. Electronically, due to difficulties with translation to WordPerfect format, this report is appended as Micropropagation.doc.

A report on the artificial screening of the germplasm accessions that may be resistant to *Entomosporium* was completed and follows. It should be noted that this study is incomplete due to the termination of the Native Fruit Program. Further verification of the results of the screening needs to be done, followed by field trials of more mature plants, and ultimately incorporation of this material into a breeding program.

Effects Of Explant Juvenility, *In Vitro* Etiolation And Subculture Number And Length On *Ex Vitro* Rooting Of Micropropagated Saskatoons (*Amelanchier alnifolia* Nutt.)

ABSTRACT

Successful micro-propagation of saskatoons (*Amelanchier alnifolia* Nutt., Rosaceae) is limited by the problem of unsuccessful rooting. *In vitro* rooting has yielded erratic results and plants are difficult to establish in soil or an artificial medium. The objective of this study was to improve the rooting of micro-propagated saskatoons by using an *ex vitro* method. The effects of explant juvenility, *in vitro* etiolation and subculture number and length on *ex vitro* rooting were tested and possible mechanisms of these effects were examined.

Shoot tips taken from the saskatoon cultivars Smoky and Thiessen with differing maturity states (juvenile vs. mature) were initiated, proliferated on a modified MS medium, and then rooted under *ex vitro* conditions after every four weeks in culture. Etiolation was applied to some cultures at the beginning of each subculture for two weeks.

The percentage of plantlets rooted, the mean number of roots/plantlet and the mean length of roots/plantlet were all greater for plantlets derived from juvenile growth tissues. The rooting percentage was 64% for plantlets from juvenile source tissues, which was significantly higher than the rooting percentage (48%) for plantlets from mature source tissues. Etiolation also increased rooting in regard to the parameters measured. Etiolated plantlets rooted with a higher percentage (61%) compared to non-etiolated plantlets (51%). The combination of both explant juvenility and etiolation had an additive effect on rooting. Etiolated plantlets from juvenile source tissues produced the highest mean number of roots/plantlet (3.7) and the highest mean length of roots/plantlet (2.7 cm). The rooting percentage increased with time following rooting, from 33% at 10 days, to 66% at 20 days, and to 70% at 30 days. Plantlets of the cultivar Smoky rooted with a higher percentage (60%) than plantlets of the cultivar Thiessen (52%).

Decapitation reduced rooting in both juvenile and mature source tissues. Decapitation caused more than a 25% reduction in the percentage of plantlets rooted for juvenile source tissues and an almost 40% reduction in the percentage of plantlets rooted for mature source tissues. Exogenous application of IBA partially overcome the inhibitory effect of decapitation and increased rooting from 41% to 60% in decapitated plantlets. IBA did not increase root formation in non-decapitated plantlets.

There was a progressive increase in rooting with increasing number and length of subcultures. The percentage of plantlets rooted was 30% for the first subculture, 48% for the second, 65% for the third, and 68% for the fourth subculture. The stimulatory effect of explant juvenility and *in vitro* etiolation persisted in the first four subcultures. Longer subculture period also increased rooting. Plantlets derived from 6-week long subcultures rooted better than those from 4-week long subcultures (rooting percentages of 71% and 65% respectively).

Higher endogenous levels of auxins, or higher auxin to cytokinin ratios associated with juvenile source tissues and *in vitro* etiolation, lowered auxin levels caused by decapitation, and

reduced cytokinin levels, or increased auxin to cytokinin ratios resulting from longer or more subculture periods may be responsible for these results. Quantitative analyses of growth regulator levels, mainly auxins and cytokinins, or isolation and identification of rooting cofactors and rooting inhibitors in micro-cuttings, may further support these hypotheses.

In general, the results of this study indicated that using explants from juvenile source tissues, applying etiolation *in vitro* and using more and longer subcultures would improve *ex vitro* rooting of micro-propagated saskatoons.

1. INTRODUCTION

The saskatoon (*Amelanchier alnifolia* Nutt., Rosaceae) is a fruit crop native to North America. It is a shrub or small tree and bears pome fruits. Serviceberry, juneberry or shadbush are other commonly used names for the saskatoon (Miller and Stushnoff, 1971). The saskatoon is increasing in importance as a prairie fruit crop because it has great potential as a commercial fruit crop for the fresh fruit market and for the processing and freezing industries (St-Pierre, 1992). In 2002, there were 417 hectare of the saskatoon planted and 450,000 kg of saskatoon fruit produced in Saskatchewan, ranking the saskatoon as the most important fruit crop in Saskatchewan (Anonymous, 2002). Continued orchard establishment of saskatoons requires efficient methods of plant propagation. In the past, traditional propagation methods could only provide a limited supply of plants due to genetic variability from seed propagation, incompatibility from grafting and difficulty in rooting by cuttings (Harris, 1961, 1972; Wallace and Graham, 1976). Tissue culture technology has overcome these limitations by providing methods for larger scale propagation. There are limited reports of *in vitro* propagation of saskatoons (Harris, 1980, 1985; Pruski *et al.*, 1990). Although a high shoot multiplication rate could be achieved, rooting was a problem. *In vitro* rooting has yielded inconsistent results and plantlets have difficulty in subsequent establishment (Harris, 1985). *Ex vitro* rooting was found superior to *in vitro* rooting since an acclimatization period was not required and transplantation losses were reduced to a minimum (Pruski *et al.*, 1990). In this thesis I try to improve the rooting of micro-propagated saskatoon plantlets and thus develop a more successful and efficient method of propagation.

Rooting of micro-propagated plantlets is influenced by a variety of factors. Juvenile explants are usually easier to root than mature explants (Kester, 1976; Jones *et al.*, 1985; Lee and Rao, 1986). Etiolation of shoots is known to stimulate rooting (Fuchigami and Moeller, 1978; Ferradini *et al.*, 1996). Rejuvenation occurs during subculture *in vitro* that is characterized by increased rooting potential, and longer subculture periods, which are characterized by higher auxin to cytokinin ratios, generally have beneficial effects on rooting (Jones and Murashige, 1974; Standardi, 1982; A-Lucas and Mullins, 1984; Amin and Jaiswal, 1988; Webster and Jones, 1989; Marks, 1991).

Consequently, the objective of this study was to determine the effects of explant juvenility, *in vitro* etiolation and subculture number and length on *ex vitro* rooting of micro-propagated saskatoons, and to examine possible mechanisms of these effects.

It was hypothesized that explants from juvenile source tissues, and *in vitro* etiolation of plantlets, are associated with higher endogenous levels of auxins, or higher auxin to cytokinin ratios, which consequently would increase the percentage of plantlets rooted, and root number and root length of these plantlets, and that the combination of juvenile source tissues, and *in vitro* etiolation of plantlets, would have a additive effect on the rooting parameters measured.

It was predicted that exogenous applications of IBA and successive subcultures would enhance rooting in all plantlets, regardless of explant sources or etiolation treatment, and that an auxin inhibitor (TIBA) or decapitation, and shorter subculture periods (generally characterized by lower auxin to cytokinin ratios) would reduce the percentage of plantlets rooted, and root number and root length of all plantlets.

2. LITERATURE REVIEW

2. 1 Adventitious Root Formation In Plants

2. 1. 1 Root Types And Origins

There are two basic morphological types of root systems: taproot systems and fibrous root systems. Taproot systems mainly occur in dicotyledous plants and are comprised of a primary root that originates in the embryo and lateral roots that are produced from the pericycle. The primary root gives rise to branched lateral roots; the younger lateral roots are near the root tip and the older ones are near the base of the root. In monocotyledons, the primary root is short-lived and the root system mainly develops from adventitious formation in which no one root is more prominent than any other, thus forming a fibrous root system (Raven *et al.*, 1999).

Adventitious roots can be defined as roots that arise from any plant part other than from the embryonic roots and their branches (Hartmann *et al.*, 1990). There are two types of adventitious roots, pre-formed roots and wound roots. Pre-formed roots can develop naturally on intact stems when they are still attached to the parent plant. Brace roots on corn (*Zea mays*), and air roots formed on some trees are examples of pre-formed roots. Wound roots are formed only after cuttings are made and they are considered to be formed *de novo* (Davies *et al.*, 1982).

The location of the origin of adventitious roots varies among species and may be associated with vascular bundles, phloem, epidermis, pericycle, cortex, cambium, lenticels or pith (Carlson, 1929; McVeigh, 1938; Ginzburg, 1967; Blazich and Heuser, 1979; Harbage *et al.*, 1993; St-Hilaire *et al.*, 1996).

2. 1. 2 Stages In The Rooting Process

Various stages of *de novo* adventitious root formation have been observed histologically. Girouard (1967) and Davies *et al.* (1982) described adventitious root formation as a four-stage process: 1) an induction phase in which partially differentiated parenchyma cells undergo dedifferentiation and remeristemation and revert to meristematic cells; 2) an initiation phase in which root initials are formed as cells begin to divide and form slightly organized groups; 3) an organization phase in which differentiation of root primordia occurs; 4) a growth phase in which primordia elongate and develop into roots. Three phases have been reported in the differentiation of root primordia of *Pinus radiata* seedlings: 1) a pre-initiative phase with no histological changes; 2) an initiative phase forming a meristematic locus; and 3) a post initiative phase with meristemoids differentiating into root primordia (Smith and Thorpe, 1975a).

Despite the inconsistencies in classifying stages of adventitious root formation, researchers agree that there must be cells capable of dividing and differentiating into root initials for successful root formation (McGuire, 1980; Christianson and Warnick, 1988). The inability of cuttings to form adventitious roots may be attributed to the inability of parenchyma cells to transform into root primordia for physiological reasons (Snyder, 1974).

2. 1. 3 Physiological Basis Of Adventitious Root Formation

2. 1. 3. 1 Effects Of Genotype

The rooting ability of shoots is strongly influenced by genotype. Some genotypes are easy-to-root while others are difficult-to-root (Capuana and Lambardi, 1995; St-Hilaire *et al.*, 1996). In evaluating the genetic effect on adventitious root formation in eighteen ecotypes of *Arabidopsis*, King and Stimart (1998) noted that the mean root number varied from 1.7 to 23.1. Mutation may lead to a complete loss of rooting ability. Rooting has been observed to positively relate to transcription, translation and subsequent RNA and protein metabolism (Molnar and LaCroix, 1972).

The genetically-based potential of rooting ability can be positively or negatively modified by the environment to which cuttings are exposed. Sometimes modifying culture conditions can alleviate genetic restrictions on rooting. Welander (1995) observed that there were significant differences in the rooting ability of birch (*Betula* spp.) cuttings from different genotypes. Rooting percentage and root number could be increased by growing cuttings in a 16 h photoperiod with a day/night temperature of 15/25 °C. A temperature of 16 °C decreased root production. Plants of varying genotypes require specific medium components or environmental conditions for successful rooting.

2. 1. 3. 2 Growth Regulators

2. 1. 3. 2. 1 Auxins

Auxins are an important factor involved in rooting as they promote adventitious root formation in the vast majority of species (Dunn and Townsend, 1954; Walkey, 1972; Lane, 1979; Welander and Huntrieser, 1981; Lineberger, 1983; Abdullah *et al.*, 1989; Watad *et al.*, 1992a; Baraldi *et al.*, 1993; Yu and Reed, 1995; Karhu, 1997; Kim *et al.*, 1998; Pruski *et al.*, 2000; Al-Salem and Karam, 2001).

There are mainly three types of auxins used in rooting: naturally occurring indole-3-acetic acid (IAA), synthetic naphthalene-acetic acid (NAA) and indole-3-butyric acid (IBA). Plants respond quite differently to these auxins due to the different ability of tissues to take up and metabolize them. In their studies on the effectiveness of IAA, NAA and IBA on adventitious root formation of *Malus* 'Jork 9'(apple) *in vitro*, De Klerk *et al.* (1997) showed that the use of NAA (3 μM) resulted in 8 roots/plant, IAA (10-100 μM) and IBA (10 μM) resulted in 15 roots/plant. Sometimes mixtures of auxins are required for proper root formation. A mixture of

NAA and IBA had an additive effect on rooting of *Vitis labrusca* (grape) micro-cuttings (Lewandowski, 1991). The auxin content in the rooting zone is positively related to the number of roots initiated while reduced levels of auxins have been implicated in the failure of rooting. This suggests that an optimum level is required for adventitious root formation (Hermberg, 1954; Weigel *et al.*, 1984).

Requirements for auxins are not the same at each stage of rooting. A higher auxin content is needed during the induction stage than the initiation stage. Once roots are induced, levels of auxins should be decreased in order for root initiation and elongation to occur (Lane, 1978; Barghchi and Alderson, 1985). Successful rooting of *Pieris floribunda* (pieris) was obtained only by *in vitro* rooting on a woody plant medium containing IBA for 10 days, followed by a transfer to a medium lacking IBA (Starrett *et al.*, 1993). *Ex vitro* rooting is advantageous because auxins can be leached out with irrigating water over the course of rooting (Karhu, 1997). The initiation stage also can be divided into an auxin-sensitive stage and an auxin-insensitive stage. During the auxin-sensitive stage that lasts about four days, auxins must be supplied continuously for root formation, either from terminal, or lateral buds, or from exogenous application. During the auxin-insensitive stage, withholding auxins does not adversely affect root formation. When apple micro-cuttings were cultured on an IBA-free medium, De Klerk *et al.* (1995) found that the rooting percentage varied from 30%, to 60%, to 70%, to 40% when a 2 μM IBA pulse was applied at 0-24 h, 24-48 h, 48-72 h and 72-96 h respectively. The promotion of rooting was largest for the IBA-pulse given at 48-72 h after excision.

There is a widespread recognition of polar transport of auxins. Endogenous IAA that is produced from terminal and lateral buds is transported downward to the base of cuttings where it stimulates rooting (Hollis and Tepper, 1971; Albert, 1975; Eliasson and Areblad, 1984; Cambridge and Morris, 1996). The velocity of this movement is about 5 to 20 mm/hr (Estelle, 1998). The polar secretion theory and the chemiosmotic theory have been advanced to explain this basipetal transportation (Hertel *et al.*, 1972; Thomson *et al.*, 1973; Rubery and Sheldrake, 1974; Raven, 1975). When the shoot apex and the lateral buds are removed, root formation is reduced. Koukourikou-Petridou and Bangerth (1997) found that decapitation of plants caused a decrease in IAA content compared with the control and a reduction by more than half in the number of roots. However, this effect was alleviated by the application of NAA to the cut apex. In their experiment with three easy-to-root and three difficult-to-root woody species, Marks and Simpson (2000) reported that when apices or axillary buds were removed from explants, rooting decreased and the time to root increased. Exogenous application of IBA generally overcame this trend.

Basipetal IAA transport can also be interrupted by inhibitors such as TIBA (2, 3, 5-triiodobenzoic acid) and NPA (1-N-naphthylphthalamic acid) (Thomson *et al.*, 1973; Batten and Goodwin, 1981; Jarvis and Shaheed, 1986; Guerrero *et al.*, 1990). Marks (1996) found that the rooting percentage was reduced from 100% to 23% and the number of roots per rooted shoot decreased from 4.3 to 1.3, when the TIBA concentration was increased from 0 to 10.0 μM in studies with *Betula* (birch).

Auxins can exist either as a free or conjugated state. Conjugation can occur with an amide or an ester. The conjugation is reversible and this is regarded as a means to regulate the active concentration of auxin (Nordstrom and Eliasson, 1991). It has been observed that prior to rooting, there is an accumulation of IAA in the rooting zone, followed by the rapid disappearance of IAA and the appearance of IAA conjugates (Collet and Lee, 1987; Liu and Reid, 1992). In their attempt to quantify the endogenous IAA and IAAsp (indole-3-acetylaspartic acid) levels during adventitious root formation in avocado (*Persea americana* Mill) micro-cuttings, Garcia-Gomez *et al.* (1994) observed that IAA levels remained constant throughout the rooting process, but that IAA levels increased two-fold during the first six days in IBA-treated cuttings. The addition of 20 μM TIBA decreased IAA levels and inhibited root formation. The IAAsp level showed a large increase before root differentiation occurred then decreased gradually.

The rooting ability of cuttings is also closely associated with enzyme activity, primarily that of peroxidases and IAA oxidases, which can enzymatically degrade IAA and regulate concentrations of auxins during rooting (Chibbar *et al.*, 1979). Peroxidase activity increased during the initiation and development of roots in *Hydrangea* spp. (hydrangea) (Molnar and LaCroix, 1972). A decrease in enzyme activity is correlated with the availability of a high concentration of auxin for root induction. A subsequent increase in enzyme activity and a lowered concentration of IAA were related to root initiation and elongation (Mato and Vieitez, 1986). Bhattacharya and Nanda (1978) observed that free IAA levels declined prior to root initiation because of increased IAA oxidase activity. Chibbar *et al.* (1980) demonstrated that peroxidase activity was a prerequisite to root initiation rather than induction.

In contrast, there are also observations that endogenous auxin levels remain constant during the entire rooting process (Stoltz, 1968; Brian and Halevy, 1973; Greenwood *et al.*, 1976). Additionally, there are observations that in some easy-to-root cuttings, the endogenous levels of auxin decrease significantly over the course of rooting (Bose *et al.*, 1973).

Rooting cofactors can act synergistically with IAA to promote rooting (Kling *et al.*, 1988). Easily-rooted species have a larger content of such cofactors, while in difficult-to-root species, these factors may be reduced or absent (Nelson and Pepper, 1965; Heuser, 1976). An endogenous root-promoting factor was isolated from cuttings of an easily-rooted pear cultivar, but not in similar cuttings of a difficult-to-root cultivar. In addition, this material only appeared in cuttings with buds treated with IBA (Fadl and Hartmann, 1967a). The nature of the rooting cofactors is unclear. Some authors postulated that they might be oxygenated terpenoids, isochlorogenic acid, or lipid-like or phenolic compounds (Hess, 1961b, 1965; Hackett, 1969; Nemeth, 1986).

Endogenous rooting inhibitors also exist in certain difficult-to-root plants and this explains why rooting could not occur (Fadl and Hartmann, 1967a, 1967b). Mature, difficult-to-root cuttings lack rooting cofactors but have inhibiting compounds. These inhibitors are absent in easy-to-root juvenile and etiolated cuttings (Hess, 1961a).

In summary, plants can be divided into three classes in regard to adventitious root formation: 1) plants with high endogenous auxin levels and all factors necessary for rooting, where no exogenous auxins are needed (Tabachnik and Kester, 1977; Noiton *et al.*, 1992); 2) plants with naturally occurring cofactors but limiting auxins, where rooting is greatly increased with the application of auxins (Gavidia *et al.*, 1996; Kim *et al.*, 1998; Pruski *et al.*, 2000); and 3) plants lacking one or more internal cofactors, or which contain rooting inhibitors, where external application of auxins gives little or no response.

Among 50 *Pyrus* (pear) species and cultivars examined for rooting ability *in vitro*, Reed (1995) noted only two accessions which formed roots on a growth-regulator-free medium, 28 accessions which rooted poorly with IBA treatment, 18 accessions with a rooting percentage 50% or higher using a 15-second 10 μM IBA dip followed by growth on the medium without growth regulators and 12 accessions rooted on the medium with 10 μM IBA applied for one week followed by culture on medium with no growth regulators, with a rooting percentage varying from 28% to 83%.

IAA can act as a gene activator and initiate early formation of root primordia. The role of IBA is to conjugate endogenous IAA with amino acids, thus leading to the synthesis of the specific protein that is necessary for the formation of root initials (Haissig, 1974).

2. 1. 3. 2. 2 Cytokinins

In general, cytokinins have been accepted as inhibitors of adventitious root formation. Exogenously applied synthetic cytokinins normally inhibit root initiation in stem cuttings (Schraudolf and Reinert, 1959; Okoro and Grace, 1978; Stenlid, 1982; Selby *et al.*, 1992; Stimart *et al.*, 1998). Root formation *in vitro* is also inhibited by the high concentrations of cytokinins used to induce shoot multiplication during the proliferation stage (Griffis *et al.*, 1983). Additionally, various types of cytokinins have been found to inhibit the rooting of apple micro-cuttings (De Klerk *et al.*, 2001). This is the reason why shoots and roots cannot form spontaneously in culture in most species. A different medium, either regulator free or containing auxins alone, is needed for root formation (Jones *et al.*, 1977).

Cytokinins may be carried over from the proliferation stage and will inhibit rooting during the rooting stage. Ben-Jaacov *et al.* (1991) showed when shoots of *Alberta magna* (natal flam bush) were cultured on the cytokinin-free medium during the proliferation stage, they would root in three weeks on a medium containing NAA. If 1 mg/l benzylaminopurine (BA) was included in the multiplication medium, eight weeks of culture on a root-inducing medium was required for rooting to commence.

Some steps can be taken to reduce the level of cytokinins in shoots in advance of the rooting stage. Shoots may be cultured on a medium containing reduced cytokinins for one or two subcultures before rooting (Stimart, 1986), or on a medium without cytokinins immediately preceding rooting (Schwarz, 1987), or the proliferation stage can be left longer than usual (Jones and Murashige, 1974). In peony (*Paeonia suffruticosa* Andr.) micro-cuttings taken from a five-week subculture, 87% rooting was obtained, while a 4-week subculture resulted in only 22-50% rooting (Bouza *et al.*, 1994). Spontaneous root formation often occurs during the proliferation stage if plants can be micro-propagated without cytokinins, or at the end of the normal proliferation stage when cytokinins in the medium become depleted (Levy, 1985).

The influence of cytokinins on root formation differs with the stages of root formation (Smith and Thorpe, 1975b; Davies and Joiner, 1980). Applying BA at intervals after cuttings of *Pisum sativum* were made, Eriksen (1974) found that high concentration of BA (1000 μM) inhibited the early stage of adventitious root formation, but the effect of inhibition decreased during later development. Lower concentrations of BA (10-100 μM) were stimulatory during the earlier stage. Eriksen (1974) concluded that once root primordia were initiated, they became capable of controlling cytokinin levels and thus were not responsive to exogenous cytokinin application during the later stages of adventitious root formation. Chandra *et al.* (1973) showed that BA at 10 μM or higher concentrations prevented phloem parenchyma cells from differentiating into root primodia only if applied during the early period of root induction. In rooting of *Malus* 'Jork 9' shoots after 24 h pulses of 1 μM BA at 0-24, 24-48, 48-72, 72-96, 96-120 and 120-144 h, De Klerk *et al.* (1995) found that the BA treatment at 48-72 h had the greatest inhibitory effect on the rooting percentage and the number of roots per rooted shoot. The rooting percentage was almost zero at the 48-72 h pulse treatment, but increased to 35% and 45% at the 24-48 and 72-96 h treatments respectively.

In contrast, there are also some observations that cytokinins, especially at low levels, may have a beneficial or stimulatory effect on rooting (Nemeth, 1979). Frett and Smagula (1981) found that the *ex vitro* rooting percentage of lowbush blueberry (*Vaccinium corymbosum* L.) was positively correlated with the concentrations of 2-iP (isopentil adenine) added to the proliferation medium, suggesting that rooting was stimulated by the presence of residual cytokinins.

There are significant differences between the cytokinin levels of juvenile and mature plants. It has been observed that cytokinins attain a higher concentration in juvenile plants than in mature plants prior to the breaking of bud dormancy and thus may be correlated with the known difference in rooting capacity between juvenile and mature cuttings (Hendry *et al*, 1982a, 1982b). In studies of cytokinin activity during root formation, Okoro and Grace (1978) found that cuttings of difficult-to-root *Populus* (poplar) species contained higher cytokinin activity than cuttings of easy-to-root species. Decapitation results not only in a decrease of IAA, but also a simultaneous increase in cytokinin content at the base of cuttings (Koukourikou-Petridou and Bangerth, 1997).

Cytokinins may not directly promote the rooting of cuttings, but may play an indirect role in rooting through effects on rejuvenation and carbohydrate load. Starch accumulation could be used as a biochemical marker for root primordium emergence (Li and Leung, 2000). High BA and low sucrose are correlated with the presence of juvenile characters. Rejuvenation also occurs during a series of subcultures. When apple shoots were grown on a medium containing BA under prolonged culture, a partial reversion to the juvenile state occurred, accompanied by changes in leaf shape and greatly improved rooting ability (Sriskandarajah *et al*., 1982).

Cytokinins also delay leaf senescence. There is a positive correlation between rooting percentage and the number of leaves retained on the cuttings (Reuveni and Raviv, 1981). A significant delay in leaf shedding and an increase in rooting of a difficult-to-root avocado (*Persea americana* Mill) cultivar were observed by applying a foliar spray containing 500 μM BA (Raviv and Reuveni, 1984).

Cytokinins may also protect auxins from degradation by decreasing indoleacetic acid oxidase activity, thus increasing auxin activity in root tissues (Noor-Saleh, 1981).

2. 1. 3. 2. 3 Gibberellins

Gibberellins are usually observed to inhibit adventitious root formation either in micro-cuttings or conventional cuttings in many species (Haissig, 1972; Hansen, 1975; Smith and Thorpe, 1975b; Ernstsen and Hansen, 1986; Welander *et al.*, 1989). Inhibition is increased with increasing concentrations of gibberellins. However enhanced root formation in the presence of gibberellins was observed in several species and under certain environmental conditions (Hansen, 1976).

These discrepancies are likely due to the use of different plant species, different culture conditions and gibberellins applied at different developmental stages of root formation. Brian *et al.* (1960) found that gibberellins must be applied either within 48 h prior to taking cuttings or within the first 24 h after taking cutting to be inhibitory. Apparently gibberellins prevent differentiated stem tissues from becoming meristematic (Brian *et al*, 1960). Iwasaki *et al.* (1986) found that gibberellins interfere with nucleic acid and protein synthesis processes during root initiation.

An interaction between gibberellins and auxins also exists. The inhibitory effect on rooting by gibberellins may be partially relieved by the simultaneously application of IAA or IBA (Kato, 1958). Bhattacharya and Nanda (1978) found a synergistic effect between gibberellins and IAA in that the stimulatory effect of gibberellins on rooting was increased by the simultaneous application of IAA.

2. 1. 3. 3 Effects Of Tissue Maturity

During the course of their development, plants pass through a series of consecutive stages. The juvenile growth phase is the initial phase of a woody plant life cycle and is characterized by phenotypic features distinct from the adult phase. Leaves may have different shapes, distinct color, or special cuticles. Shoots may have a different kind of bark and retain their leaves in winter (Marks and Simpson, 1993). The stem may possess spines or thorns (Borchert, 1976). Branches may have a different growing habit. In the juvenile phase, side branches tend to grow orthotropically, but in the mature phase, plagiotropically (Heybroek and Visser, 1976).

There are two different concepts of aging in a plant, namely the chronological age and the physiological age. The time that has elapsed since the plant germinated is referred to as chronological aging. Physiological aging refers to the phase of growth. A plant ages physiologically from the base to the top and from the inner to the outer parts. In fact the lower parts of a plant which are the oldest in the chronological sense actually are the most juvenile under the physiological concept, while the more recently formed peripheral tissues are physiologically the most mature (Borchert, 1976; Fortanier and Jonkers, 1976).

Basal parts of mature trees, root suckers, stump sprouts, epicormic shoots and sphaeroblasts are sources of juvenile materials (Heybroek and Visser, 1976). There are also a number of methods that can be used to induce juvenility, including hedging and heavy pruning of stock plants (Fortanier and Jonkers, 1976; Schwabe, 1976), serial grafting of mature, difficult-to-root clones onto juvenile stocks (Muzik and Cruzado, 1958; Huang *et al.*, 1992), re-rooting the apex as a cutting (Lee and Rao, 1986), serial cutting propagation (Greenwood, 1987), ring barking, girdling, etiolation and blanching (Delargy and Wright, 1979), application of spray pastes or injections of growth substances (gibberellins, growth retardants) (Kester, 1976), and serial subcultures of tissue *in vitro* (Economou and Read, 1986; Webster and Jones, 1989; Marks, 1991; Chang *et al*, 2001).

One of the most important attributes of juvenility is its favorable effect on rooting (Fuchigami and Moeller, 1978; Lyrene, 1980, 1981; Vieitez *et al.*, 1985; Goldfarb *et al.*, 1996). Numerous examples in the literature show that juvenile materials root more easily, and quickly, with higher rooting percentages, more roots and longer roots. In conventional propagation, cuttings from mature parts of a plant are found to be more difficult to root than those taken from juvenile shoots. Olive (*Olea europaea* L.) juvenile cuttings taken from the base of trees over 5 years old rooted faster, in a higher percentage and formed more roots per cutting than adult cuttings taken from the upper portion of the trees (Porlingis and Therios, 1976). Redcedar (*Juniperus virginiana*) stem cuttings taken from the lower third of the crown of 30-year-old trees rooted at a significantly higher percentage (67%) than cuttings taken from the middle third (43 %) (Henry *et al.*, 1992). This has also been observed *in vitro*. Although Arrillaga *et al.* (1991) were able to establish shoot cultures from shoot apices and nodal segments from both 30-day-old seedlings and 30-year-old trees of *Sorbus domestica* (sorbus), 75-85% of shoots from juvenile materials formed roots, but only 30% rooting was obtained from mature shoots. Gupta *et al.* (1980) obtained similar results with *Tectona grandis* L. (teak). Over 80% of the micro-cuttings from seedling explants rooted, while the rooting percentage of explants from mature shoots was only 10% in the primary culture.

Some cultures derived from mature materials may not produce any roots at all. Chevre *et al.* (1983) obtained some roots on shoots from chestnut (*Castanea mollissima* Blume) seedlings, but did not get any roots on shoots from adult materials.

A certain amount of rejuvenation takes place when tissues are cultured *in vitro* and cultures become more easily managed after a period of time (Stoutemyer and Britt, 1963; Davies and Hartmann, 1988; Webster and Jones, 1989; Marks, 1991). Some characteristic features of the juvenile phase of growth may occur in plants cultured *in vitro* (Swartz, 1983; Greenwood, 1987; San-Jose *et al.*, 1988).

It has been found that shoots cultured *in vitro* are easier to root than cuttings propagated by conventional methods. The rooting percentage was higher in *Rhododendron* micro-cuttings from *in vitro* cultures than in cuttings from traditionally raised stock plants (Marks, 1991).

Rooting also is increased with successive subcultures. The rooting rate of guava (*Psidium cattleianum* Sabine) shoots was 33% in the initial culture, 70% in the fifth subculture and 90% in the tenth subculture (Amin and Jaiswal, 1988). Sometimes improved rooting potential is not immediately obvious, but begins after several subcultures and increases with subsequent cultures. No roots were formed in *Prunus* (prune) micro-cuttings in the first four subcultures, but rooting percentages increased to 72% for the fifth, 82% for the sixth and up to 90% for the seventh subculture (A-Lucas and Mullins, 1984). Nodal cuttings from original plants of the apple cultivars Jonathan and Delicious failed to give roots. Shoots from the initial culture and the first subculture rooted with very low frequency with 8%, 32% for Jonathan and 5%, 15% for Delicious. After the ninth subculture, 95% of Jonathan micro-cuttings rooted whereas the rooting percentage of Delicious was 21% after the fourth subculture and 79% after 31 subcultures (Sriskandarajah *et al.*, 1982).

It has been found that genetic, physiological and anatomical changes take place when plants enter into the mature phase from the juvenile phase. Different genes are expressed in the juvenile and mature phase (Millikan and Ghosh, 1971; Rogler and Dahmus, 1974). Differences in the shoot apices of the two phases exist, and they are responsible for the different morphological characters observed in the juvenile and mature phases (Wareing and Frydman, 1976). Hormonal levels are also different. Juvenile tissues contain higher levels of auxins and gibberellins and lower levels of abscisic acid (Kester, 1976; Wareing and Frydman, 1976.) Lack of balanced hormone levels is also responsible for decreased rooting ability in mature materials (Vieitez, 1976; Vieitez, *et al.*, 1994).

Anatomical structures may also differ. Greater development of secondary vascular tissues occurs in mature shoots (Ballester *et al.*, 1999). Sclerenchyma bands bordering the phloem are formed in mature shoots and constitute a mechanical barrier for emerging adventitious root primodia (Mahlstede and Watson, 1952; Goodin, 1965). Many juvenile tissues and easy-to-root plants contain substances called rooting cofactors which are capable of stimulating root initiation, while rooting inhibitors are correlated with a decrease in root initiation in mature plants (Heuser, 1976; Vieitez, 1976; Barghchi, 1986). Juvenile tissues may contain auxin-protecting substances that prevent the destruction of IAA by enzymes (Stonier and Yoneda, 1967).

2. 1. 3. 4 Effects Of Tissue Etiolation

The growth and development of plants is dependent on light for photosynthesis and photomorphogenesis. Light quality (wavelength), duration (photoperiod) and illuminance (flux density) all influence growth and morphogenesis (Murashige, 1974).

Etiolation is the development of plants or plant parts in the absence of light, or at low levels of irradiance (Hartmann *et al.*, 1990). Skotomorphogenesis occurs when plants grow in the dark; there is no leaf expansion and a functional photosynthetic apparatus is not formed. This results in pale elongated shoots, small un-expanded leaves and lack of chlorophyll (Maynard and Bassuk, 1985). Shading, blanching, banding, stooling and air layering are practical techniques of etiolation (Frolich, 1961; Maynard and Bassuk, 1987).

The most important attribute of tissue etiolation is its ability to enhance rooting. Many studies have shown that etiolation has a stimulatory effect on rooting, both in traditional cuttings and *in vitro*. The rate of rooting of shoot tip culture of 12 woody species and cultivars of

Rosaceae was increased when cultures were incubated in the dark for one week followed by light incubation (Norton and Boe, 1982). In a difficult-to root almond (*Prunus amygdalus* Batch) cultivar, 55% rooting was induced by imposed dark treatment for four days (Rugini and Verma, 1982).

Sometimes absolute darkness is not necessary. Fewer roots were formed in cuttings from pea (*Pisum sativum*) stock plants grown at 38 W m^{-2} than those at 16 W m^{-2} (Hansen, 1975). The number of roots formed in the light decreased as plants were grown under condition of progressively higher irradiance. The greatest number of roots was formed on explants taken from plants grown at 7.4 W m^{2}, and the least number of roots on those grown at 68.1 W m^{2} (Hansen, 1976).

In preparing conventional cuttings, etiolation can be applied by putting whole stock plants in the dark before cuttings are excised (Howard, 1982; Maynard and Bassuk, 1987), by etiolating the potential cuttings before they are excised (Ballester *et al.*, 1989), by etiolating potential rooting zone before cuttings are excised from stock plants (Nelson, 1987), or by putting cuttings in the dark after excision and etiolating the rooting zone after cuttings are excised (Kawase, 1965).

In vitro etiolation can be applied to entire shoots or just to stems at the base of cuttings during the proliferation stage or during the rooting stage. Whole explants can be placed in the dark by using dark rooms or by covering the containers (Hammerschlag, 1982; Lemos and Blake, 1996). Light can be kept away from the rooting zone by darkening the media with charcoal, lampblack or graphite (Bressan *et al.*, 1982), or by covering the base of vessels with opaque materials, such as black tapes, or by painting containers black (Calvo and Segura, 1989). When cuttings are rooted *ex vitro*, shoot bases are denied light by being placed into a rooting substrate.

The duration of darkness has a key effect on rooting, in some cases, the longer the duration, the better. However, if the dark treatment is too long, rooting may be impaired. In plum (*Prunus cerasifera* Ehrh.) shoot cultures, complete rooting (100%) was obtained if the cultures were incubated in the dark for two weeks, in contrast to cultures rooted in light (23.3%), or incubated in the dark for one week (46%) (Hammerschlag, 1982). No roots were observed when proliferated shoots of *Ribes nigrum* (currant) were incubated under a 16 h photoperiod. An initial 3-day- dark treatment increased rooting to 83%, but dark periods of 5 days and 10 days reduced rooting to 10% and 0% respectively (Ma *et al.*, 1992).

The beneficial effects of etiolation on rooting were reported in many other studies (Gardner, 1937; Lanphear and Meahl, 1960; Hansen and Eriksen, 1974; Delargy and Wright, 1978; Delargy, 1979; Druart *et al.*, 1982; Harrison-Murrey, 1982; Meyer, 1982; Bassuk and Maynard, 1987). However, etiolation does not invariably enhance root formation. For example, the percentage of plants rooted was not improved by etiolation in nodal cuttings of pecan (*Carya illinoensis*) seedlings (Hansen and Lazarte, 1984).

The mechanism of the stimulatory effect of etiolation on rooting is not fully understood, but differences between etiolated and non-etiolated shoots have been observed which might be contributed to the differences in rooting.

Anatomical differences between etiolated and non-etiolated tissues exist. Etiolated stems have thinner cell walls, and lack a fiber sheath found in non-etiolated tissues (Bid and Mukherjee, 1972). Much less sclerification, a possible mechanical barrier to adventitious root formation, was found in etiolated stems of *Malus* clone (Doud and Carlson, 1977). Etiolation produces elongated succulent shoots, which can increase the proportion of undifferentiated parenchymatic cells that can be induced to form root initials (Herman and Hess, 1963). Irradiance causes suberization of stem tissues which may act as an anatomical barrier to root emergence (Williams *et al.*, 1984).

Physiological changes also occur. Light is known to reduce free endogenous IAA (Famiani *et al.*, 1994). Auxin activity is greater in etiolated stem tissues. It has been observed that auxin activity in stem tissues was decreased by 80% after 24 h irradiance, but only decreased 56% after 48 h in the dark (Kawase, 1965). The basipetal transport of auxins differs markedly between light and dark grown tissues. Auxins are transported more efficiently in light grown stems and more slowly in dark grown stems. This results in more evenly distributed levels of auxins. This favors the formation of more root initials and results in the production of more scattered and numerous roots (Eliasson, 1980; Maynard and Bassuk, 1987). Etiolation greatly enhances the sensitivity of stem tissues to auxins. A large basal build up of auxins is needed to stimulate root initiation in light grown stems, while stems grown in the dark respond to lower auxin levels (Pierik and Steegmans, 1975). Translatable factors produced in etiolated segments may also enhance rooting (Bassuk and Maynard, 1987).

2. 2 Propagation Of *Amelanchier alnifolia*

2. 2. 1 Conventional Propagation

Traditionally, the saskatoon has been propagated by both sexual and asexual methods. Seed propagation is the most popular way to propagate saskatoons because it is inexpensive, simple and easy. However, seedlings may not be identical to their parents due to genetic variation and only 70% to 90% may be true-to-type (Wallace and Graham, 1976; Robinson and Partanen, 1980; St- Pierre, 1999). Valuable characters, such as fruit size, quantity and quality, may be lost. Plants grown from seeds take longer to produce fruits. Additionally, the germination rate is inconsistent and seedlings do not have uniform high quality (Howe, 1976; Robinson, 1982).

Vegetative or asexual propagation is thought to be a desirable way to produce uniform plants and to preserve the identity of a selected cultivar (Harris, 1965). It also shortens the time to fruit production compared to seedlings (Hartmman *et al.*, 1990).

Cuttings, grafting and division are vegetative methods usually used to propagate the saskatoon (Bishop, 1979; St-Pierre, 1999), but each has its limitations.

Hardwood cuttings are very difficult to root and the rooting percentage is almost zero (Harris, 1961; Fung, 1984; Mazza and Davidson, 1993). Softwood cuttings can be rooted more effective than hardwood cuttings, with rooting ranging from 13% to 40%, but root development and survival are very poor, and the plants are slow to grow (Harris, 1970, 1972; Miller and

Stushnoff, 1971; Bishop and Nelson, 1976, 1980; Casement, 1976; Cummings, 1976). Root cuttings root well, but it is difficult to obtain enough root material and the parent plants are damaged when cuttings are taken (Harris, 1961).

Grafting onto Cotoneaster rootstock has been used with limited success, but successful grafting requires special skills and is very time consuming (Anonymous, 1976; Wallace and Graham, 1976). Incompatibility may also occur (Wallace, 1978).

Suckers, which develop from rhizomes, can be used as a source of division. However, sucker development is variable among different cultivars of the saskatoon, and the intensive labor involved, and thus increased cost, limits its application (Wright, 1973; Cummings, 1976). In general, traditional propagation methods can not produce sufficient plants to meet the increasing demand.

2. 2. 2 *in vitro* Propagation

2. 2. 2. 1 *in vitro* Propagation

There are limited reports of *in vitro* propagation of saskatoons. Harris (1980) first reported success in shoot tip culture in the saskatoon with the cultivar Smoky. Although shoot multiplication rate was high (an average of 10 shoots per culture every four weeks), rooting was inconsistent; rooting percentages ranging from 0-100% were observed in repeated tests. Pruski *et al.* (1990) successfully cultured four cultivars of the saskatoon (Northline, Pembina, Smoky and Thiessen) using shoot tips and dormant buds as explants. They found there were significant differences in cultivar response to different culture conditions and treatments in regard to shoot development and rooting ability. Rooting was done in non-sterile conditions and *ex vitro* rooting was found to be superior to *in vitro* rooting. Struve and Lineberger (1985) produced *Amelanchier laevis* plantlets using *in vitro* rooting and outdoor acclimation. By manipulating various concentrations of growth regulators, Lineberger (1981) obtained rapid shoot multiplication and increased rooting in shoot tip culture of *Amelanchier laevis*.

2. 2. 2. 2 Methods Of Rooting Micro-cuttings

Usually shoots are produced during the proliferation stage because the treatments used to induce shoots inhibit root formation. In order to obtain plantlets, a separate rooting stage is necessary for most species (Norton and Boe, 1982; Mackay *et al.*, 1995). However, in some easily rooted species, roots can be formed spontaneously during shoot production and the rooting stage is not required (Hussey and Stacey, 1981; Herrera *et al.*, 1990; Bansal and Pandey, 1993).

There are two methods for rooting micro-cuttings, namely *in vitro* and *ex vitro* rooting. In *in vitro* rooting, roots are formed in sterile conditions and subsequently transferred to an exterior environment (Jones and Hopgood, 1979; Jones *et al.*, 1979; Zimmerman and Broome, 1981; Jones *et al.*, 1985; Welander, 1983; Watad *et al.*, 1992b). When *ex vitro* rooting, micro-cuttings are treated as conventional cuttings and rooted in planting substrates directly (Wong, 1982; Griffis, *et al.*, 1983; Levy, 1985; Daguin *et al.*, 1992; Isutsa *et al.*, 1994; Edson *et al.*, 1997; Pruski *et al.*, 2000).

Each method has its own advantages and disadvantages. In the early days of tissue culture, *in vitro* rooting was widely used and this method is still the only practical method of rooting some species (Alderson *et al.*, 1988; Shibli *et al.*, 1997). Losses may be less if shoots are rooted *in vitro* before being planted (Turner *et al.*, 1987). The main disadvantages of *in vitro* rooting include increased overall cost of micro-propagation (McCulloch *et al.*, 1992), roots may be easily damaged as plantlets are removed from culture, increasing chances of infection with fungal or bacterial disease (Maene and Debergh, 1983), roots may lack root hairs, vascular connections and a secondary cambium (McClelland *et al.*, 1990), or there is poor establishment when the plants are transferred to soil (Hutchinson, 1984; Edson *et al.*, 1997). In chestnut micro-cuttings, a higher *in vitro* rooting percentage (97%) was obtained than *ex vitro* (77%), but only 50% of micro-plants with *in vitro*-developed roots survived during acclimatization compared to 100% survival of those with *ex-vitro* developed roots (Goncalves *et al.*, 1998).

Roots formed *in vitro* and *ex vitro* often have different appearances. Roots formed *in vitro* are short, brittle, dark and un-branched while roots formed *ex vitro* are long, white, flexible and branched with root hairs. Additionally, shoots rooted *in vitro* tend to produce horizontally growing roots whereas vertically growing roots are obtained in *ex vitro* rooting (McClelland *et al.*, 1990; Rogers and Smith, 1992).

Ex vitro rooting is commonly used in commercial micro-propagation labs because it reduces overall cost (Borkowska *et al.*, 1999). This method is especially beneficial for woody plants. Roots formed *in vitro* usually lack a vascular cambium and secondary development is deterred. Secondary thickening is important for the survival of plantlets in woody species, otherwise the plantlets easily die (Brand and Lineberger, 1986; Katase 1993, 1994).

3. MATERIALS AND METHODS

3. 1 Plant Materials

Two explant sources of differing maturity of two cultivars of saskatoons were used. Mature explants were collected from 10-year-old plants of the cultivars Smoky and Thiessen grown in the experimental plots of the Department of Plant Sciences, University of Saskatchewan, Saskatoon, Canada. Shoot tips were taken from branches at the top of mature plants in June 2001. Juvenile explants were collected from 2-year-old seedlings of the cultivar Smoky and suckers of the cultivar Thiessen at the same time.

In a repeated experiment in June 2002, all plant materials were collected from Riverbend Plantation, Saskatoon, Saskatchewan. Mature explant materials were collected from the tops of 10-year-old plants and juvenile explants from suckers.

Explants were sterilized in 70% ethanol for 5 seconds, followed by immersion for 10 minutes in a 10% solution of sodium hypochlorite containing 0.1% Tween 80, then rinsed 3 times, 5 minutes each with sterile water.

3. 2 Initiation

Explants were aseptically dissected to remove external leaves, and shoot tips of 3-5 mm length were inoculated on to a modified Murashige and Skoog (MS) medium supplemented with 30 g/l sucrose, 1 mg/l BAP, 0.1 mg/l IBA, 10.4 mg/l thiamine HCL and 100 mg/l myo-inositol. The medium was adjusted to pH 5.7 and solidified with 8 g/l agar. Explants were grown in petri dishes with 20 ml medium, 5 shoot tips per dish. All cultures were incubated in a culture chamber at 24/22 °C day/night temperature, 16 h photoperiod at an intensity of 40 $\mu E\ m^{-2}s^{-1}$, provided by cool white fluorescent light for four weeks. Explants were then transferred to a proliferation medium.

3. 3 Proliferation

The proliferation medium was similar to the initiation medium, but with 2 mg/l BAP, 80 mg/l adenine, 170 mg/l $NaH_2PO_4.H_2O$ and 7 g/l agar. Elongated explants were placed vertically on 30 ml medium in 100 ml magenta boxes and grown for four weeks in the same environmental conditions as the initiation stage. After every four weeks, micro-cuttings for rooting experiments were taken, or shoots were cut into leafy segments 1-2 cm long, and subcultured.

3. 4 Rooting

Proliferated shoots produced *in vitro* were used for all rooting studies. All rooting studies were evaluated after four weeks. The rooting medium consisted of clay soil, vermiculite and perlite (3:1:1 v/v). Clumps of shoots were separated into single shoots 2-3 cm long with 2 or 3 broad leaves. Rooting was conducted in plastic trays with 60 cells each under non-sterile conditions in a mist bed in the greenhouse. The mist bed was adjusted to water 30 seconds every half hour to maintain a high humidity condition.

3. 5 Experimental Treatments

Elongated explants of the two cultivars of the saskatoon Smoky and Thiessen, each with the two differing maturities, were transferred to the proliferation medium from the initiation medium and cultured in magenta boxes each with 5 explants. One-third were etiolated, one-third left non-etiolated and one-third were subcultured to maintain the experiments. After every four weeks, explants were either transferred to a new proliferation medium to begin a new subculture or micro-cuttings were taken for rooting experiments.

The etiolation treatment was applied at the beginning of each subculture by covering magenta boxes with black plastic for two weeks. Plants were then cultured under the same light conditions as non-etiolated plants for another two weeks. Four experiments were conducted:

1) The first experiment was conducted to determine the effects of explant maturity, *in vitro* etiolation, time following rooting (10, 20, and 30 days) and cultivar on *ex vitro* rooting of micro-propagated saskatoons. For each experimental treatment, 24 micro-cuttings were used. The experiment was repeated twice.

2) The second experiment was conducted to determine the effects of explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA and cultivar on *ex vitro* rooting of micro-propagated saskatoons. Decapitation involved the removal of the shoot apices of 2-3 mm length with small scissors. Exogenous application of IBA was made by dipping the bases of micro-cuttings into rooting powder (0.1% IBA) prior to being placed into the rooting substrates. For each experimental treatment, 24 micro-cuttings were used. The experiment was repeated twice. One experiment was conducted using TIBA (2, 3, 5-triiodobenzoic acid), an inhibitor of IAA basipetal transportation. Problems were encountered as TIBA only dissolved in a high concentration of ethanol. Micro-cuttings died when treated with this solution, therefore the use of TIBA was abandoned.

3) The third experiment was conducted to determine the effects of explant maturity, *in vitro* etiolation, number of subcultures and cultivar on *ex vitro* rooting and shoot production of micro-propagated saskatoons. The first four subcultures were tested. For each experimental treatment, 24 micro-cuttings were used. The experiment was repeated twice.

4) The fourth experiment was conducted to determine the effects of explant maturity, *in vitro* etiolation, length of subculture period and cultivar on *ex vitro* rooting of micro-propagated saskatoons. Two subculture periods, four weeks and six weeks, were examined. For each experimental treatment, 24 micro-cuttings were used. The experiment was repeated twice.

3. 6 Data Collection And Statistical Analysis

The experiments in this study were established as factorials within a completely random experimental design. The number of rooted plantlets, the number of roots per plantlet and the length of roots per plantlet were recorded after four weeks of rooting. In experiment 1, data were collected at 10 days, 20 days and 30 days after rooting respectively. All sets of data were subjected to analysis of variance and regression analysis using the SAS computer program. The significance of difference was determined with a t-test. All statistical calculations were based on the original measurements. Transformed data (arcsin, square root and logarithm) did not aid in the analysis of the experimental results. Because there was no significant difference between experiments conducted in 2001 and 2002, the results in this study were a combination of data of these two experiments.

4. RESULTS

4. 1 Effects Of Explant Maturity, *in vitro* Etiolation, Time Following Rooting And Cultivar On *ex vitro* Rooting Of Micro-propagated Saskatoons

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, time following rooting and cultivar all significantly affected *ex vitro* rooting in regard to the percentage of plantlets rooted (Appendix table A.1). A higher percentage of plantlets from juvenile source tissues (64%) rooted as compared to plantlets from mature source tissues (48%) (Table 4.1). Etiolation significantly increased the percentage of plantlets rooted (Table 4.1). Rooting percentages were 51% and 61% in non-etiolated and etiolated plantlets respectively. Rooting percentages increased with time following rooting, from 33% at 10 days, to 66% at 20 days, and to 70% at 30 days after rooting (Table 4.1). Plantlets of the cultivar Smoky rooted at a higher percentage (60%) than plantlets of the cultivar Thiessen (52%) (Table 4.1).

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, time following rooting, cultivar and the interaction between explant maturity and etiolation significantly affected *ex vitro* rooting in regard to the mean number of roots/plantlet (Appendix table A.2). Juvenile source tissues, both non-etiolated and etiolated, resulted in a higher mean number of roots/plantlet than mature source tissues. Etiolation increased the mean number of roots/plantlet both in plantlets from juvenile (2.9 to 3.7) and mature source tissues (2.0 to 2.4) and had greater effects on plantlets from juvenile source tissues than on plantlets from mature source tissues (Table 4.2). The combination of juvenile source tissues and etiolation had an additive effect on rooting.

Table 4.1 Effects of explant maturity, *in vitro* etiolation, time following rooting and cultivar on the percentage of plantlets rooted (%) of micro-propagated saskatoons (N=1152).

Treatment	Treatment Category	Percentage of Plantlets Rooted (S.E.)[1]	
Explant Maturity	Juvenile	64a	(0.01)
	Mature	48b	(0.01)
in vitro Etiolation	Non-etiolated	51b	(0.01)
	Etiolated	61a	(0.01)
Time Following Rooting	10 days	33c	(0.01)
	20 days	66b	(0.01)
	30 days	70a	(0.01)
Cultivar	Smoky	60a	(0.01)
	Thiessen	52b	(0.01)

[1] - standard error.

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

Table 4.2 Effects of explant maturity, *in vitro* etiolation, time following rooting and cultivar on the mean number of roots/plantlet of micro-propagated saskatoons (N=1152).

Treatment	Treatment Category	Treatment Interaction	Mean Number of Roots/Plantlet (S.E.)[1]	
Explant Maturity	Juvenile	Non-etiolated	2.9b	(0.08)
		Etiolated	3.7a	(0.07)
	Mature	Non-etiolated	2.0d	(0.08)
		Etiolated	2.4c	(0.10)
Time Following Rooting	10 days		2.1c	(0.09)
	20 days		2.9b	(0.06)
	30 days		3.3a	(0.06)
Cultivar	Smoky		3.1a	(0.06)
	Thiessen		2.4b	(0.06)

[1] - standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

Etiolated plantlets from juvenile source tissues had the greatest mean number of roots (3.7). Non-etiolated plantlets from juvenile source tissues produced a higher mean number of roots than etiolated plantlets from mature source tissues. The mean number of roots/plantlet increased from 2.1 at 10 days, to 2.9 at 20 days, and to 3.3 at 30 days after rooting (Table 4.2). Plantlets of the cultivar Smoky produced a higher mean number of roots (3.1) than plantlets of the cultivar Thiessen (2.4) (Table 4.2).

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, time following rooting, cultivar, and the interactions between explant maturity and etiolation, explant maturity and time, etiolation and time, etiolation and cultivar significantly affected *ex vitro* rooting in regard to the mean length of roots/plantlet (Appendix table A.3). Etiolation increased the mean length of roots in plantlets from juvenile source tissues, but had no effect on plantlets from mature source tissues (Table 4.3). The stimulatory effects of explant juvenility on the mean length of roots/plantlet were persistent at 10 days, 20 days and 30 days after rooting and differences between plantlets from juvenile and mature source tissues increased with time (Table 4.3). Etiolation had no effect on the mean length of roots/plantlet at 10 days after rooting, but had stimulatory effects at 20 days and 30 days after rooting (Table 4.3). Etiolation also increased the mean length of roots/plantlet in both the cultivars Smoky and Thiessen (Table 4.3). Plantlets of the cultivar Smoky produced a greater mean length of roots than plantlets of the cultivar Thiessen. However there was no difference in the mean length of roots/plantlet between etiolated plantlets of the cultivar Thiessen and non-etiolated plantlets of the cultivar Smoky (Table 4.3). Figure 4.1 illustrated the adventitious root

Table 4.3 Effects of explant maturity, *in vitro* etiolation, time following rooting and cultivar on the mean length of roots/plantlet of micro-propagated saskatoons (N=1152).

Treatment	Treatment Category	Treatment Interaction	Mean Length of Roots/Plantlet in cm (S.E.)[1]	
Explant Maturity	Juvenile	Non-etiolated	1.8b	(0.08)
		Etiolated	2.7a	(0.07)
	Mature	Non-etiolated	1.2c	(0.10)
		Etiolated	1.5c	(0.08)
Time Following Rooting	10 days	Juvenile	0.8e	(0.11)
		Mature	0.4 f	(0.15)
	20 days	Juvenile	2.2c	(0.08)
		Mature	1.3d	(0.09)
	30 days	Juvenile	3.7a	(0.07)
		Mature	2.4b	(0.09)
Time Following Rooting	10 days	Non-etiolated	0.5e	(0.14)
		Etiolated	0.7e	(0.11)
	20 days	Non-etiolated	1.4d	(0.09)
		Etiolated	2.0c	(0.08)
	30 days	Non-etiolated	2.7b	(0.08)
		Etiolated	3.5a	(0.08)
Cultivar	Smoky	Non-etiolated	1.7b	(0.08)
		Etiolated	2.4a	(0.08)
	Thiessen	Non-etiolated	1.4c	(0.09)
		Etiolated	1.7b	(0.08)

[1] - standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

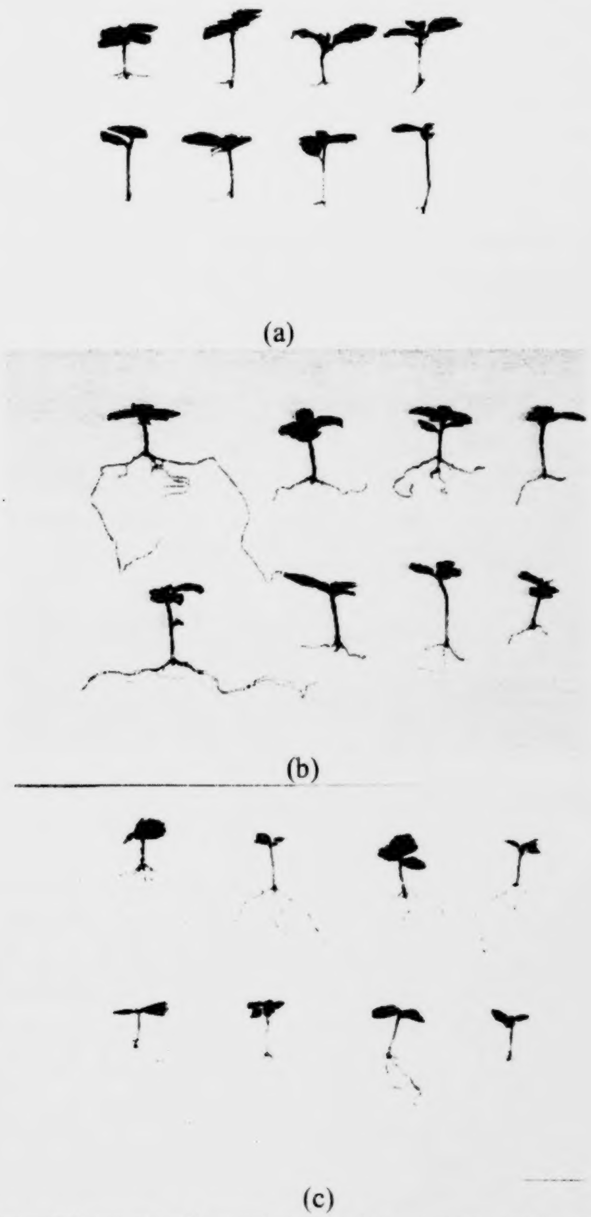

Figure 4.1 Adventitious root formation in micro-propagated saskatoons at (a)10 days, (b) 20 days and (c) 30 days following rooting. Back row (left to right): etiolated cv Smoky from a juvenile source, non-etiolated cv Smoky from a juvenile source, etiolated cv Smoky from a mature source and non-etiolated cv Smoky from a mature source. Front row (left to right): etiolated cv Thiessen from a juvenile source, non-etiolated cv Thiessen from a juvenile source, etiolated cv Thiessen from a mature source and non-etiolated cv Thiessen from a mature source.

formation in micro-propagated saskatoons at 10 days, 20 days and 30 days after rooting.

4. 2 Effects Of Explant Maturity, *in vitro* Etiolation, Decapitation, Exogenous Application Of IBA And Cultivar On *ex vitro* Rooting Of Micro-propagated Saskatoons

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA, cultivar and the interactions between decapitation and explant maturity, and decapitation and exogenous application of IBA significantly affected *ex vitro* rooting in regard to the percentage of plantlets rooted (Appendix table A.4). *In vitro* etiolation increased the rooting percentage. Rooting percentages were 57% and 66% for non-etiolated and etiolated plantlets respectively (Table 4.4). A higher percentage of plantlets from juvenile source tissues rooted as compared to plantlets from mature source tissues, in both the decapitation and non-decapitation treatments (Table 4.4). Decapitation resulted in more than a 25% reduction in the percentage of plantlets rooted from juvenile source tissues and almost 40% reduction in the percentage of plantlets rooted from mature source tissues. Plantlets from non-decapitated, mature source tissues rooted at a higher percentage (66%) than decapitated plantlets from juvenile source tissues (60%). Exogenous application of IBA increased the percentage of plantlets rooted from 41% to 60% in decapitated plantlets, but had no stimulatory effect on non-decapitated plantlets (Table 4.4). Plantlets of the cultivar Smoky rooted with a higher percentage (64%) than plantlets of the cultivar Thiessen (58%) (Table 4.4).

Table 4.4 Effects of explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA and cultivar on the percentage of plantlets rooted (%) of micro-propagated saskatoons (N=1536)

Treatment	Treatment Category	Treatment Interaction	Percentage of Plantlets Rooted (S.E.)[1]	
in vitro Etiolation	Non-etiolated		57b	(0.00)
	Etiolated		66a	(0.00)
Decapitation	Decapitated	Juvenile	60c	(0.01)
		Mature	41d	(0.01)
	Non-decapitated	Juvenile	79a	(0.01)
		Mature	66b	(0.01)
Decapitation	Decapitated	- IBA	41c	(0.01)

		+ IBA	60b	(0.01)
	Non-decapitated	- IBA	73a	(0.01)
		+ IBA	71a	(0.01)
Cultivar	Smoky		64a	(0.00)
	Thiessen		58b	(0.00)

[1]- standard error
Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA, cultivar and the interactions between explant maturity and etiolation, and exogenous application of IBA and explant maturity significantly affected *ex vitro* rooting in regard to the mean number of roots/plantlet (Appendix table A.5). Etiolation increased the mean number of roots/plantlet in plantlets from both juvenile (2.9 to 4.0) and mature source tissues (2.1 to 2.6), but affected plantlets from juvenile source tissues more than plantlets from mature source tissues (Table 4.5). The combination of both explant juvenility and etiolation had an additive effect. Etiolated plantlets from juvenile source tissues produced the greatest mean number of roots/plantlet (4.0). Plantlets from juvenile source tissues produced a higher mean number of roots with or without exogenous application of IBA, and exogenous application of IBA increased the mean number of roots in plantlets from both juvenile (3.3 to 3.6) and mature source tissues (2.1 to 2.6) (Table 4.5). Plantlets from juvenile source tissues without exogenous application of IBA produced a higher mean number of roots (3.3) than plantlets from mature source tissues with exogenous application of IBA (2.6). Decapitation resulted in an almost 30% reduction in the mean number of roots/plantlet (Table 4.5). Plantlets of the cultivar Smoky produced a higher mean number of roots (3.3) than plantlets of the cultivar Thiessen (2.5) (Table 4.5).

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA, cultivar and the interactions between explant maturity and etiolation, decapitation and explant maturity, exogenous application of IBA and explant maturity, and cultivar and explant maturity significantly affected *ex vitro* rooting in regard to the mean length of roots/plantlet (Appendix table

Table 4.5 Effects of explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA and cultivar on the mean number of roots/plantlet of micro-propagated saskatoons (N=1536)

Treatment	Treatment Category	Treatment Interaction	Mean Number of Roots/Plantlet (S.E.)[1]	
Explant Maturity	Juvenile	Non-etiolated	2.9b	(0.05)
		Etiolated	4.0a	(0.06)
	Mature	Non-etiolated	2.1d	(0.07)
		Etiolated	2.6c	(0.06)
Decapitation	Non-decapitated		3.3a	(0.04)
	Decapitated		2.4b	(0.05)
Application of IBA	- IBA	Juvenile	3.3b	(0.06)
		Mature	2.1d	(0.06)
	+ IBA	Juvenile	3.6a	(0.05)
		Mature	2.6c	(0.06)
Cultivar	Smoky		3.3a	(0.04)
	Thiessen		2.5b	(0.04)

[1] - standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at 0.05 level.

A.6). Etiolation increased the mean length of roots/plantlet in plantlets from both juvenile (2.7 cm to 4.0 cm) and mature source tissues (1.7 cm to 2.1cm) and had greater effects on plantlets from juvenile source tissues than those from mature source tissues (Table 4.6). The combination of juvenile source tissues and etiolation had an additive effect on rooting. Etiolated plantlets from juvenile source tissues had the greatest mean length of roots (4.0 cm). Plantlets from juvenile source tissues produced a greater mean length of roots than plantlets from mature source tissues under both decapitated and non-decapitated conditions; decapitation had greater effects on plantlets from mature source tissues as compared to plantlets from juvenile source tissues (Table 4.6). Decapitation resulted in a 20% reduction in the mean length of roots/plantlet in plantlets from juvenile source tissues and an almost 40% reduction in the mean length of roots/plantlet in plantlets from mature source tissues. Exogenous application of IBA increased the mean length of roots/plantlet from 3.2 cm to 3.5 cm in plantlets from juvenile source tissues and from 1.6 cm to 2.3 cm in plantlets from mature source tissues and had greater effects on plantlets from mature source tissues than on plantlets from juvenile source tissues (Table 4.6). Etiolation increased the mean length of roots/plantlet in plantlets from both cultivars Smoky and Thiessen and had greater effects on plantlets of the cultivar Smoky than on plantlets of the cultivar Thiessen (Table 4.6). Etiolation increased the mean length of roots/plantlet from 2.4 cm to 3.4 cm in plantlets of the cultivar Smoky, and from 2.1 cm to 2.8 cm in plantlets of the cultivar Thiessen. Etiolated plantlets of the cultivar Thiessen produced a higher mean length of roots/plantlet than non-etiolated plantlets of the cultivar Smoky.

Table 4.6 Effects of explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA and cultivar on the mean length (cm) of roots/plantlet of micro-propagated saskatoons (N=1536)

Treatment	Treatment Category	Treatment Interaction	Mean Length of Roots/Plantlet in cm (S.E.)[1]	
Explant Maturity	Juvenile	Non-etiolated	2.7b	(0.05)
		Etiolated	4.0a	(0.05)
	Mature	Non-etiolated	1.7d	(0.06)
		Etiolated	2.1c	(0.05)
Decapitation	Decapitated	Juvenile	3.0b	(0.05)
		Mature	1.5d	(0.06)
	Non-decapitated	Juvenile	3.7a	(0.04)
		Mature	2.4c	(0.05)
Application of IBA	- IBA	Juvenile	3.2b	(0.05)
		Mature	1.6d	(0.06)
	+ IBA	Juvenile	3.5a	(0.05)
		Mature	2.3c	(0.05)
Cultivar	Smoky	Non-etiolated	2.4c	(0.05)

		Etiolated	3.4a	(0.05)
	Thiessen	Non-etiolated	2.1d	(0.06)
		Etiolated	2.8b	(0.05)

[1] - standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

4. 3 Effects Of Explant Maturity, *in vitro* Etiolation, Number of Subcultures And Cultivar On *ex vitro* Rooting And Shoot Production Of Micro propagated Saskatoons

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, number of subcultures and cultivar significantly affected *ex vitro* rooting in regard to the percentage of plantlets rooted (Appendix table A.7). Plantlets from juvenile source tissues rooted with a higher percentage (62%) than plantlets from mature source tissues (44%) (Table 4.7). Etiolation increased the rooting percentage (57%) compared to non-etiolation (49%) (Table 4.7). Rooting percentages also were increased with increasing number of subcultures, from 30%, to 48%, to 65%, and to 68% for the first four subcultures respectively (Table 4.7). The percentage of plantlets rooted was more than doubled at the fourth subculture, as compared to the first subculture. Plantlets of the cultivar Smoky rooted at a higher percentage (56%) than plantlets of the cultivar Thiessen (50%) (Table 4.7).

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, number of subcultures, cultivar and the interactions between explant maturity and etiolation, etiolation and cultivar significantly affected *ex vitro* rooting in regard to the mean number of roots/plantlet (Appendix table A.8). Etiolation increased the mean number of roots in plantlets from both juvenile (2.4 to 3.6) and mature source tissues (1.7 to 2.1) and had greater effects on plantlets from juvenile than on plantlets from mature source tissues (Table 4.8). The combination of explant juvenility and etiolation had an additive effect. Etiolated plantlets from juvenile source tissues produced the highest mean number of roots/plantlet (3.6). The mean number of roots/plantlet increased with

Table 4.7 Effects of explant maturity, *in vitro* etiolation, number of subcultures and cultivar on the percentage of plantlets rooted (%) of micro-propagated saskatoons (N=1536).

Treatment	Treatment Category	Percentage of Plantlets Rooted (S.E.)[1]	
Explant Maturity	Juvenile	62a	(0.01)
	Mature	44b	(0.01)

in vitro Etiolation	Non-etiolated	49b	(0.01)
	Etiolated	57a	(0.01)
Subculture	1	30d	(0.01)
	2	48c	(0.01)
	3	65b	(0.01)
	4	68a	(0.01)
Cultivar	Smoky	56a	(0.01)
	Thiessen	50b	(0.01)

[1]- standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

Table 4.8 Effects of explant maturity, *in vitro* etiolation, number of subcultures and cultivar on the mean number of roots/plantlet of micro-propagated saskatoons (N=1536).

Treatment	Treatment Category	Treatment Interaction	Mean Number of Roots/Plantlet (S.E.)[1]	
Explant Maturity	Juvenile	Non-etiolated	2.4b	(0.06)
		Etiolated	3.6a	(0.05)
	Mature	Non-etiolated	1.7d	(0.07)
		Etiolated	2.1c	(0.06)
Subculture	1		1.9d	(0.08)
	2		2.3c	(0.06)
	3		2.7b	(0.05)
	4		2.9a	(0.05)
Cultivar	Smoky	Non-etiolated	2.2c	(0.06)

	Etiolated	3.1a	(0.05)
Thiessen	Non-etiolated	1.9d	(0.07)
	Etiolated	2.6b	(0.06)

[1]- standard error
Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

subcultures, from 1.9, to 2.3, to 2.7, and to 2.9 for the first four subcultures respectively (Table 4.8). Etiolation also increased the mean number of roots in plantlets of both cultivars Smoky (2.2 to 3.1) and Thiessen (1.9 to 2.6), but had greater effects on plantlets of the cultivar Smoky than on plantlets of the cultivar Thiessen (Table 4.8). Etiolated plantlets of the cultivar Thiessen produced a higher mean number of roots than non-etiolated plantlets of the cultivar Smoky.

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, number of subcultures, cultivar and the interactions between explant maturity and etiolation, and etiolation and cultivar significantly affected *ex vitro* rooting in regard to the mean length of roots/plantlet (Appendix table A.9). Etiolation increased the mean length of roots/plantlet in plantlets from both juvenile (2.0 cm to 3.3 cm) and mature source tissues (1.4 cm to 1.6 cm), but had greater effects on plantlets from juvenile source tissues than on plantlets from mature source tissues (Table 4.9). The combination of explant juvenility and etiolation had an additive effect. Etiolated plantlets from juvenile source tissues produced the highest mean length of roots/plantlet (3.3 cm). The mean length of roots/plantlet increased with additional subcultures, from 1.3 cm, to 1.9 cm, to 2.4 cm, and to 2.7 cm for the first four subcultures respectively (Table 4.9). Etiolation also increased the mean length of roots in plantlets from both the cultivars Smoky (1.9 cm to 2.9 cm) and Thiessen (1.5 cm to 2.0 cm), but had greater effects on plantlets of the cultivar Smoky than on plantlets of the cultivar Thiessen (Table 4.9). There was no difference in the mean length of roots/plantlet in etiolated Thiessen and non-etiolated Smoky plantlets.

Table 4.9 Effects of explant maturity, *in vitro* etiolation, number of subcultures and cultivar on the mean length (cm) of roots/plantlet of micro-propagated saskatoons (N=1536).

Treatment	Treatment Category	Treatment Interaction	Mean Length of Roots/ Plantlet in cm (S.E.)[1]	
Explant Maturity	Juvenile	Non-etiolated	2.0b	(0.05)
		Etiolated	3.3a	(0.05)
	Mature	Non-etiolated	1.4d	(0.07)
		Etiolated	1.6c	(0.06)
Subculture	1		1.3d	(0.08)
	2		1.9c	(0.06)
	3		2.4b	(0.05)
	4		2.7a	(0.05)
Cultivar	Smoky	Non-etiolated	1.9b	(0.06)
		Etiolated	2.9a	(0.05)
	Thiessen	Non-etiolated	1.5c	(0.06)
		Etiolated	2.0b	(0.06)

[1]- standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

The ANOVA for this experiment indicated that explant maturity, number of subcultures, cultivar and the interaction between explant maturity and cultivar significantly affected the mean number of shoots/explant (Appendix table A.10). Explants from juvenile tissues produced a higher mean number of shoots/explant (4.9) than those from mature source tissues (3.4) (Table 4.10). The mean number of shoots/explant increased with the increasing number of subcultures, from 1.8, to 3.5, to 5.0, and to 6.4 for the first four subcultures respectively (Table 4.10). In both cultivars Smoky and Thiessen, explants from juvenile sources produced a higher mean number of shoots than from mature sources, but there was no difference in the mean number of shoots/explant between the cultivars Smoky and Thiessen from mature sources. Explants of the cultivar Smoky from juvenile sources produced the same mean number of shoots/explant as those of the cultivar Thiessen from mature sources (Table 4.10).

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, number of subcultures, cultivar and the interaction between the explant maturity and number of subcultures significantly affected the mean length of shoots/explant (Appendix table A.11). Explants from juvenile sources consistently produced greater mean length of shoots than explants from mature sources in the first four subcultures (Table 4.11). Rejuvenation occurred with sustained subcultures (Table 4.11). Explants from juvenile tissues in the second subculture produced the same mean length of shoots as explants from mature tissues in the third subculture, as did explants from juvenile tissues in the third subculture and explants from mature tissues in the fourth subculture. Explants of the cultivar Thiessen produced a greater mean length of shoots than explants of the cultivar Smoky (Table 4.11).

Table 4.10 Effects of explant maturity, number of subcultures and cultivar on the mean number of shoots /explant of micro-propagated saskatoons (N=400).

Treatment	Treatment Category	Treatment Interaction	Mean Number of Shoots/Explant (S.E.)[1]	
Explant Maturity	Juvenile		4.9a	(0.05)
	Mature		3.4b	(0.05)
Subculture	1		1.8d	(0.07)
	2		3.5c	(0.07)
	3		5.0b	(0.07)
	4		6.4a	(0.07)
Cultivar	Smoky	Juvenile	3.6b	(0.07)
		Mature	3.3c	(0.07)
	Thiessen	Juvenile	6.2a	(0.07)
		Mature	3.5bc	(0.07)

[1] - standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

Table 4.11 Effects of explant maturity, number of subcultures and cultivar on the mean length of shoots /explant (cm) of micro-propagated saskatoons (N=400).

Treatment	Treatment Category	Treatment Interaction	Mean Length of Shoots/Explant	in cm (S.E.)[1]
Subculture	1	Juvenile	0.8d	(0.03)
		Mature	0.6f	(0.03)
	2	Juvenile	1.0c	(0.03)
		Mature	0.7e	(0.03)
	3	Juvenile	1.1b	(0.03)
		Mature	1.0c	(0.03)
	4	Juvenile	1.2a	(0.03)
		Mature	1.1b	(0.03)
Cultivar	Smoky		0.9b	(0.03)
	Thiessen		1.0a	(0.03)

[1]- standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

4. 4 Effects Of Explant Maturity, *in vitro* Etiolation, Length Of Subculture Period And Cultivar On *ex vitro* Rooting Of Micro-propagated Saskatoons

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, length of subculture period, cultivar and the interaction between subculture period and etiolation significantly affected *ex vitro* rooting in regard to the percentage of plantlets rooted (Appendix table A.12). Plantlets from juvenile source tissues rooted with a higher percentage (73%) than plantlets from mature source tissues (63%) (Table 4.12). Etiolation increased the rooting percentage of plantlets from both 4-week (62% to 68%) and 6-week (66% to 75%) long subcultures with a greater percentage rooting in 6-week long subcultures (Table 4.12). The longer subculture period enhanced the rooting percentage in both etiolated and non-etiolated plantlets. There was no difference in the percentage of plantlets rooted in comparing non-etiolated plantlets from 6-week long subcultures and etiolated plantlets from 4-week long subcultures. Plantlets of the cultivar Smoky rooted with a higher percentage (71%) than plantlets of the cultivar Thiessen (64%) (Table 4.12)

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, length of subculture period, cultivar and the interaction between explant maturity and etiolation significantly affected *ex vitro* rooting in regard to the mean number of roots/plantlet (Appendix table A.13). Etiolation increased the mean number of roots/plantlet in plantlets from both juvenile (2.8 to 3.8) and mature source tissues (2.1 to 2.5), with plantlets from juvenile source tissues scoring higher than plantlets from mature source tissues (Table 4.13). The combination of explant juvenility and etiolation had an additive effect. Etiolated plantlets from juvenile source tissues produced the highest mean

Table 4.12 Effects of explant maturity, *in vitro* etiolation, length of subculture period and cultivar on the percentage of plantlets rooted (%) of micro-propagated saskatoons (N= 768).

Treatment	Treatment Category	Treatment Interaction	Percentage of Plantlets Rooted(S.E.)[1]	
Explant Maturity	Juvenile		73a	(0.01)
	Mature		63b	(0.01)
Subculture Period	4 weeks	Non-etiolated	62c	(0.01)
		Etiolated	68b	(0.01)
	6 weeks	Non-etiolated	66b	(0.01)
		Etiolated	75a	(0.01)
Cultivar	Smoky		71a	(0.01)
	Thiessen		64b	(0.01)

[1]- standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

Table 4.13 Effects of explant maturity, *in vitro* etiolation, length of subculture period and cultivar on the mean number of roots/plantlet of micro-propagated saskatoons (N=768).

Treatment	Treatment Category	Treatment Interaction	Mean Number of Roots/Plantlet (S.E.)[1]	
Explant Maturity	Juvenile	Non-etiolated	2.8b	(0.08)
		Etiolated	3.8a	(0.07)
	Mature	Non-etiolated	2.1d	(0.08)
		Etiolated	2.5c	(0.08)
Subculture Period	4 weeks		2.5b	(0.05)
	6 weeks		3.1a	(0.06)
Cultivar	Smoky		3.1a	(0.05)
	Thiessen		2.4b	(0.06)

[1]- standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

number of roots (3.8). A longer subculture period increased the mean number of roots/plantlet (Table 4.13). The mean number of roots/plantlet was 2.5 for plantlets from 4-week long and 3.1 for plantlets from 6-week long subcultures. Plantlets of the cultivar Smoky produced a greater mean number of roots (3.1) than plantlets of the cultivar Thiessen (2.4) (Table 4.13).

The ANOVA for this experiment indicated that explant maturity, *in vitro* etiolation, length of subculture period, cultivar and the interaction between explant maturity and etiolation significantly affected *ex vitro* rooting in regard to the mean length of roots/plantlet (Appendix table A.14). Etiolation increased the mean length of roots in plantlets from both juvenile (2.8 cm to 3.9 cm) and mature source tissues (1.8 cm to 2.2 cm), with plantlets from juvenile source tissue scoring higher than plantlets from mature source tissues (Table 4.14). The combination of explant juvenility and etiolation had an additive effect. Etiolated plantlets from juvenile source tissues produced the greatest mean length of roots (3.9 cm). The longer subculture period increased the mean length of roots/plantlet (Table 4.14). The mean length of roots/plantlet was 2.5 cm for plantlets from 4-week long and 2.9 cm for plantlets from 6-week long subcultures. Plantlets of the cultivar Smoky produced a greater mean length of roots (3.0 cm) than plantlets of the cultivar Thiessen (2.4 cm) (Table 4.14).

Table 4.14 Effects of explant maturity, *in vitro* etiolation, length of subculture period and cultivar on the mean length (cm) of roots/plantlet of micro-propagated saskatoons (N=768).

Treatment	Treatment Category	Treatment Interaction	Mean Length of Roots/ Plantlet in cm (S.E.)[1]	
Explant Maturity	Juvenile	Non-etiolated	2.8b	(0.09)
		Etiolated	3.9a	(0.08)
	Mature	Non-etiolated	1.8d	(0.10)
		Etiolated	2.2c	(0.09)
Subculture Period	4 weeks		2.5b	(0.06)
	6 weeks		2.9a	(0.06)
Cultivar	Smoky		3.0a	(0.06)
	Thiessen		2.4b	(0.07)

[1]- standard error

Means followed by different letters within treatment groups compared (separated by lines in the table) are significantly different at the 0.05 level.

5. DISCUSSION

5. 1 Effects Of Explant Maturity, *in vitro* Etiolation, Time Following Rooting And Cultivar On *ex vitro* Rooting Of Micro-propagated Saskatoons

The results of this experiment indicated that both explant juvenility and etiolation had stimulatory effects on adventitious root formation in micro-propagated saskatoons. Differences in endogenous auxin contents may be responsible for the differences in the rooting ability of micro-propagated saskatoons from juvenile source tissues and mature source tissues. Porlingis and Therios (1976) observed that different IBA concentrations were required for juvenile and adult olive cuttings for maximal rooting, which were 250 ppm for the juvenile and 4000 ppm for the mature cuttings with rooting percentage about 85% and 60% respectively. Juvenile tissues may also contain rooting cofactors which can interact with IAA and stimulate adventitious root formation while these root-promoting substances may be lacking or rooting inhibitors may be present in mature tissues (Hess, 1961a; Heuser, 1976). Ballester *et al.* (1999) reported that more endogenous IAA was detected in mature than in juvenile chestnut micro-cuttings, indicating that the level of IAA is not the limiting factor responsible for the lack of rooting capacity in mature shoots. Welander (1983) also observed that different IBA concentrations were required for cultures derived from the juvenile growth phase and mature growth phase for maximal rooting of apple rootstocks, which were 1.25μM for the juvenile and 0.5 μM for the mature phase and concluded that some factors, rather than auxins, also controlled the rooting process.

Etiolation may increase rooting by its influence on hormonal changes. It is known that light inhibits root initiation by stimulating IAA breakdown, thus reducing levels of free endogenous IAA available for adventitious root formation (Famiani *et al.*, 1994). Norton and Boe (1982) found that a lower concentration of exogenous IBA in the medium was needed for maximal root formation when cultures were etiolated. Hammerschlag (1982) observed that the application of auxins could not completely reproduce all of the effects of etiolation and concluded that etiolation may also stimulate a synthesis of rooting cofactors or inhibit cofactor breakdown.

In the present experiment, etiolation had no effect on the mean length of roots/plantlet at 10 days after rooting in this experiment (Table 4.3). I postulate that this time period coincides with the initiation phase of adventitious root formation. During this phase, parenchyma cells de-differentiate and revert to root initials, no root elongation occurs. Eriksen (1973) also reported that roots emerged through the epidermis seven to eight days after cuttings were made.

In the current study, the combination of explant juvenility and etiolation had an additive effect on adventitious root formation. However, etiolation did not increase the mean number of roots, nor the mean length of roots in plantlets from mature source tissues to the same level as those in non-etiolated plantlets from juvenile source tissues (Table 4.2, Table 4.3). This implies that explant juvenility has more influential effects on adventitious root formation than etiolation. Etiolation cannot completely alter the physiological nature of mature source tissues.

The variation in rooting ability between the cultivars Smoky and Thiessen may reflect differences in endogenous auxin content or auxin metabolism between these two cultivars. Interestingly, etiolation increased the mean length of roots/plantlet in the cultivar Thiessen to the same level as that in non-etiolated Smoky (Table 4.3). Etiolation may change the endogenous hormone level in Thiessen. Other studies have noted that adventitious root formation is strongly affected by genetic background. Lane and McDougald (1982) reported that differences in reaction to NAA were found among dwarf apple clones; the best concentration of NAA for root production was 1.0 μM for M27, 1.0 μM for M26, 3.3 μM for M111, and M9 produced callus at all concentrations tested. James (1983a, 1983b) noted that variation in sensitivity to auxins existed in M9 and M26 apple. For maximal rooting, 1×10^{-3} μM IAA was required in M9 while only 1×10^{-4} μM was required in M26. James (1983a, 1983b) concluded that differences in the endogenous metabolism of exogenous IAA might be responsible for the differences in rooting. It is known that cv Smoky and Thiessen are not related and they have quite different genotypes. This may also be responsible for the difference in rooting ability between these two cultivars (Zatylny and St-Pierre, 2002).

5. 2 Effects Of Explant Maturity, *in vitro* Etiolation, Decapitation, Exogenous Application Of IBA And Cultivar On *ex vitro* Rooting Of Micro-propagated Saskatoons

The results of this experiment indicated that explant juvenility and *in vitro* etiolation stimulated rooting in micro-propagated saskatoons, and that plantlets of the cultivar Smoky rooted better than plantlets of the cultivar Thiessen. These confirmed the results in the previous experiment and discussion is as before.

The results of this experiment also showed that there was a relationship between the presence of active shoot apices and adventitious root formation of micro-propagated saskatoon cuttings. Decapitation caused a reduction in the percentage of plantlets rooted, the mean number of roots/plantlet and the mean length of roots/plantlet in this experiment. Plantlets from juvenile and mature source tissues responded differently to decapitation. Decapitation resulted in about a 25% reduction, and about a 40% reduction in the percentage of plantlets rooted and the mean length of roots in plantlets from juvenile and mature source tissues respectively (Table 4.4 and Table 4.6). These results suggest that plantlets derived from mature source tissues are more dependent on shoot apices for rooting than are plantlets from juvenile source tissues. It is well established that IAA, which is produced in shoot apices and axillary buds, is transported downward within stems to the base of cuttings where it stimulates root formation. When shoot apices are removed, endogenous IAA levels at the sites of formation of root primordia are reduced and rooting is impaired (Eliasson and Areblad, 1984; Cambridge and Morris, 1996). Marks (1996) showed a similar trend in the studies on the role of the shoot apex in controlling rhizogenesis in three woody plant species and found that removal of shoot apex did not affect rooting in an easy-to-root species, inhibited rooting in a difficult-to-root species and decreased rooting in an 'intermediate' species.

In the current experiment, exogenous application of IBA significantly increased the percentage of plantlets rooted in decapitated materials, but was not equivalent to a non-decapitated shoot apex (Table 4.4). These results suggest that exogenous application of auxins can partially restore the capacity to form roots after decapitation, implying that auxins are a critical factor in controlling adventitious root formation, but are not the only factor responsible for this process. Exogenous application of auxins stimulates rooting probably either directly, or by inhibiting the accumulation of cytokinins at the base of cuttings. There are some observations that decapitation not only reduces the levels of IAA but also increases cytokinin content at the base of cuttings (Koukourikou-Petridou and Bangerth, 1997). Marks and Simpson (2000) reported that one or more growth substances, which are synthesized in shoot apices, also move basipetally to the base of cuttings, where they interact with IAA and affect adventitious root formation. IAA can only induce adventitious root formation in tissues that contain competent cells that already have the ability to initiate roots. IAA does not appear to induce the formation of root primordia in non-competent cells (Haissig, 1970). Eriksen (1973) reported that decapitation had an inhibitory effect on rooting only within the first four days after cuttings were made. Decapitation at five or six days after cuttings were made had no effect on root formation. In the current study, exogenous application of IBA had no effect on the percentage of plantlets rooted in non-decapitated materials. This implies that in micro-propagated saskatoons, the endogenous auxin level is not a limiting factor for root formation and that exogenous application of auxins will not further enhance rooting micro-propagated saskatoons.

5. 3 Effects Of Explant Maturity, *in vitro* Etiolation, Number Of Subcultures And Cultivar On *ex vitro* Rooting And Shoot Production Of Micro- propagated Saskatoons

The results of this experiment indicated that explant juvenility and *in vitro* etiolation stimulated rooting in micro-propagated saskatoons, and that plantlets of the cultivar Smoky rooted better than plantlets of the cultivar Thiessen. Once again these verified the results found in the previous two experiments and discussion is as before.

In this experiment, there was a progressive increase in the percentage of plantlets rooted, the mean number of roots/plantlet, the mean length of roots/plantlet, and the mean number of shoots/explant with increasing number of subcultures. These results are consistent with those reported by other authors (Sriskandarajah *et al.*, 1982; Marks, 1991). Rejuvenation occurs with successive subcultures, which is characterized by increased rooting ability and shoot multiplication. The mechanism for this is not understood clearly. Greenwood (1987) postulated that when shoots are cultured on a cytokinin-enriched medium, they are encouraged to promote the outgrowth of lateral buds or to promote the formation of adventitious shoots. These shoots are considered to be juvenile shoots. Subsequently, when they are made into micro-cuttings, they show an increased rooting ability. Another explanation is that axillary buds may act as strong sinks for available cytokinins and divert them from stem tissues (Douglas, 1984). James and Thurbon (1981) explained the increased rooting of successive subcultures by the fall in BA concentration at the shoot bases. Tissue adjustment, which is thought to be an epigenetic change induced by specific inducers (cytokinins), may also occur during prolonged subculture conditions (Economou and Read, 1986; Norton and Norton, 1986).

In the current study, plantlets of the cultivar Smoky rooted better, but did not produce as many shoots as plantlets of the cultivar Thiessen. This may be explained by the difference in endogenous cytokinin levels between these two cultivars. Thiessen plantlets may have a higher endogenous cytokinin level or a lower auxin to cytokinin ratio. Cytokinins stimulate shoot multiplication, but inhibit root formation.

The fact that there was no difference in the mean number of shoots/explant between the cultivars Smoky and Thiessen from mature sources implies that juvenility has more influential effects on rooting.

5. 4 Effects Of Explant Maturity, *in vitro* Etiolation, Length Of Subculture Period And Cultivar On *ex vitro* Rooting Of Micro-propagated Saskatoons

The results of this experiment indicated that explant juvenility and *in vitro* etiolation stimulated rooting in micro-propagated saskatoons, and that plantlets of the cultivar Smoky rooted better than plantlets of the cultivar Thiessen. Once again these verified the results found in the previous three experiments and discussion is as before.

Culture conditions preceding the rooting stage can have an influence on root formation. Residual compounds accumulated in shoots from the proliferation medium can either stimulate or inhibit adventitious root formation. Because higher cytokinin concentrations are usually included in proliferation media to maximize shoot multiplication, it is quite possible that residual cytokinins carried over from the proliferation media have inhibitory effects on root initiation (Ben-Jaacov *et al.*, 1991). In the current study, plantlets derived from a 6-week long subculture generally rooted better than plantlets from a 4-week long subculture in terms of the parameters measured. This is probably due to the fact that increasing subculture length can reduce the cytokinin content in shoots by metabolism and therefore favor root formation. There was no difference in the percentage of plantlets rooted in non-etiolated plantlets from a 6-week long subculture and in etiolated plantlets from a 4-week long subculture, indicating that the longer culture period has a similar effect on rooting as etiolation (Table 4.12). Etiolation may increase rooting by increasing endogenous auxin levels or auxin to cytokinin ratios (Norton and Boe, 1982), while the longer subculture period enhances rooting by decreasing cytokinin levels (Bressan *et al.*, 1982). Both have stimulatory effects on rooting. I also observed that plantlets of the cultivar Thiessen had a higher shoot multiplication rate than plantlets of the cultivar Smoky, but plantlets of the cultivar Smoky were better at rooting in all the parameters measured. This may imply that plantlets of the cultivar Thiessen contain a higher endogenous cytokinin level. Cytokinins have an inhibitory effect on rooting, but a stimulatory effect on shoot multiplication.

The physiological state of explants during subcultures can also affect subsequent root formation. If the endogenous cytokinin level is too low, shoot senescence may occur and rooting would then be impaired (Bressan *et al.*, 1982). Therefore the optimum length of subcultures should maintain a cytokinin level that neither inhibits shoot formation nor reduces the vigor of cultured shoots.

5.5 General Discussion and Conclusions

In general, explant juvenility and *in vitro* etiolation had stimulatory effects on the percentage of plantlets rooted, mean number of roots/plantlet and mean length of roots/plantlet in all four experiments in this study. Additionally, the interaction between explant maturity and etiolation was also generally significant in terms of the mean number of roots/plantlet and mean length of roots/plantlet. Etiolation increased the percentage of plantlets rooted, mean number of roots/plantlet and mean length of roots/plantlet regardless of the maturity of the explant source tissues. Etiolation appeared to have greater effects on adventitious root formation in plantlets from juvenile as compared to plantlets from mature source tissues in all experiments. These results imply that the physiological state of the explants is more important in root formation. Once plants enter the mature stage, they appear to become less sensitive to the effects of etiolation. Reduced auxin levels, or the presence of rooting-inhibitors in mature plants may be responsible for this (Ma *et al.*, 1992; Vieitez *et al.*, 1994).

Plantlets from the cultivar Smoky generally rooted better than plantlets from the cultivar Thiessen in all experiments tested. Differences in genetic background and differences in endogenous auxin content or auxin metabolism between these two cultivars may have contributed to this variation.

The observations that decapitation caused a reduction in rooting and that exogenous application of IBA could partially overcome this inhibitory effect suggest that auxins are a main factor, but not the only factor involved in the rooting process.

Rooting also can be improved with increasing number and length of subcultures. This gives us a good suggestion to overcome the problem encountered in rooting of micro-propagated saskatoons.

The best percentage of plantlets rooted (88%) was obtained with etiolated juvenile tissues of the cv Smoky from the fourth subculture, compared with the worst percentage of plantlets rooted (13%) with non-etiolated mature tissues of the cv Thiessen from the first subculture. This is of importance to the commercial micro-propagation industry because the loss of plantlets will be greatly reduced by improved rooting and efficiency of propagation will be increased.

My studies have suggested some useful methods to successfully rooting micro-propagated saskatoons. Using explants from juvenile source tissues, applying etiolation treatment *in vitro*, and increasing the number of subcultures and the length of subculture period could improve *ex-vitro* rooting of micro-propagated saskatoons.

Future studies on quantitative analyses of growth regulator levels, mainly auxins and cytokinins, and isolation and identification of rooting cofactors or rooting inhibitors in micro-cuttings of saskatoon berry may further support the hypotheses in my current study.

6. LITERATURE CITED

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7. APPENDIX A

Table A.1 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, time following rooting, and cultivar on the percentage of plantlets rooted of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	0.32	195.79	0.00
Etiolation	1	0.14	85.09	0.00
Time	2	0.64	394.07	0.00

Cultivar	1	0.06	39.11	0.00
Time × Maturity	2	0.00	2.45	0.10
Time × Etiolation	2	0.00	0.02	0.98
Cultivar × Maturity	1	0.00	0.79	0.38
Cultivar × Etiolation	1	0.00	0.10	0.76
Maturity × Etiolation	1	0.00	0.08	0.78
Error	33	0.00		

Table A.2 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, time following rooting, and cultivar on the mean number of roots/plantlet of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	171.48	172.85	0.00
Etiolation	1	47.44	47.82	0.00
Time	2	56.72	57.17	0.00
Cultivar	1	59.36	59.84	0.00
Time × Cultivar	2	1.63	1.65	0.19
Time × Maturity	2	2.02	2.04	0.13
Time × Etiolation	2	2.29	2.31	0.10
Cultivar × Maturity	1	1.43	1.44	0.23
Cultivar × Etiolation	1	0.00	0.00	0.97
Maturity × Etiolation	1	7.79	7.86	0.01
Error	631	0.99		

Table A.3 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, time following rooting, and cultivar on the mean length of roots/plantlet of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	101.95	110.94	0.00
Etiolation	1	38.57	41.97	0.00
Time	2	263.32	286.55	0.00
Cultivar	1	26.47	28.81	0.00
Time × Maturity	2	8.16	8.88	0.00
Time × Etiolation	2	3.25	3.53	0.02
Cultivar × Maturity	1	2.77	3.02	0.08
Cultivar × Etiolation	1	5.29	5.76	0.02
Maturity × Etiolation	1	16.15	17.57	0.00
Error	631	0.92		

Table A.4 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA, and cultivar on the percentage of plantlets rooted of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	0.40	544.28	0.00
Etiolation	1	0.14	188.71	0.00
Decapitation	1	0.82	1112.10	0.00
IBA	1	0.12	165.81	0.00
Cultivar	1	0.06	82.35	0.00
Decapitation × IBA	1	0.17	230.44	0.00

Decapitation × Maturity	1	0.02	23.23	0.00
Decapitation × Etiolation	1	0.00	1.87	0.18
IBA × Cultivar	1	0.00	0.84	0.36
IBA × Maturity	1	0.00	0.31	0.58
IBA × Etiolation	1	0.00	0.91	0.35
Cultivar × Maturity	1	0.00	0.91	0.35
Cultivar × Etiolation	1	0.00	0.07	0.80
Maturity × Etiolation	1	0.00	2.87	0.10
Error	48	0.00		

Table A.5 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA, and cultivar on the mean number of roots/plantlet of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	270.92	344.60	0.00
Etiolation	1	128.27	163.16	0.00
Decapitation	1	138.07	175.62	0.00
IBA	1	38.21	48.60	0.00
Cultivar	1	118.17	150.31	0.00
Decapitation × IBA	1	1.79	2.28	0.13
Decapitation × Cultivar	1	0.10	1.40	0.24
Decapitation × Maturity	1	0.43	0.55	0.46
Decapitation × Etiolation	1	0.02	0.03	0.87
IBA × Cultivar	1	0.04	0.06	0.81

IBA × Maturity	1	3.53	4.49	0.03
IBA × Etiolation	1	1.09	1.39	0.24
Cultivar × Maturity	1	0.63	0.81	0.37
Cultivar × Etiolation	1	0.36	0.46	0.50
Maturity × Etiolation	1	17.92	22.79	0.00
Error	928	0.79		

Table A.6 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, decapitation, exogenous application of IBA, and cultivar on the mean length of roots/plantlet of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	447.06	736.51	0.00
Etiolation	1	155.26	255.78	0.00
Decapitation	1	149.37	246.07	0.00
IBA	1	54.79	90.26	0.00
Cultivar	1	48.73	80.28	0.00
Decapitation × IBA	1	1.34	2.20	0.14
Decapitation × Cultivar	1	0.73	1.20	0.27
Decapitation × Maturity	1	4.73	7.79	0.01
Decapitation × Etiolation	1	1.35	2.22	0.14
IBA × Cultivar	1	0.12	0.20	0.65
IBA × Maturity	1	6.30	10.38	0.00
IBA × Etiolation	1	2.16	3.56	0.06
Cultivar × Maturity	1	0.01	0.01	0.92

Cultivar × Etiolation	1	6.24	10.29	0.00
Maturity × Etiolation	1	43.07	70.95	0.00
Error	928	0.61		

Table A.7 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, number of subcultures, and cultivar on the percentage of plantlets rooted of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	0.39	412.82	0.00
Etiolation	1	0.09	97.68	0.00
Subculture	2	0.47	518.14	0.00
Cultivar	1	0.05	54.30	0.00
Subculture × Cultivar	2	0.00	1.85	0.17
Subculture × Maturity	2	0.00	0.09	0.91
Subculture × Etiolation	2	0.00	0.96	0.39
Cultivar × Maturity	1	0.00	2.92	0.10
Cultivar × Etiolation	1	0.00	0.07	0.80
Maturity × Etiolation	1	0.00	0.42	0.52
Error	33	0.00		

Table A.8 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, number of subcultures, and cultivar on the mean number of roots/plantlet of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	136.10	224.24	0.00

Etiolation	1	76.69	126.35	0.00
Subculture	2	23.36	38.49	0.00
Cultivar	1	20.83	34.31	0.00
Subculture × Cultivar	2	0.10	0.16	0.85
Subculture × Maturity	2	0.04	0.06	0.94
Subculture × Etiolation	2	0.02	0.02	0.98
Cultivar × Maturity	1	0.22	0.36	0.55
Cultivar × Etiolation	1	4.01	6.60	0.01
Maturity × Etiolation	1	22.30	36.74	0.00
Error	535	0.61		

Table A.9 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, number of subcultures, and cultivar on the mean length of roots/plantlet of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	133.08	236.84	0.00
Etiolation	1	71.27	126.83	0.00
Subculture	2	39.83	70.88	0.00
Cultivar	1	43.52	77.44	0.00
Subculture × Cultivar	2	0.20	0.36	0.70
Subculture × Maturity	2	0.15	0.26	0.77
Subculture × Etiolation	2	0.23	0.41	0.67
Cultivar × Maturity	1	1.74	3.10	0.08
Cultivar × Etiolation	1	9.45	16.82	0.00
Maturity × Etiolation	1	43.26	76.98	0.00

Error	535	0.56		

Table A.10 Analysis of variance for the effects of explant maturity, number of subcultures, and cultivar on the mean number of shoots/explant of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	90.09	454.22	0.00
Subculture	3	157.93	796.29	0.00
Cultivar	1	75.98	383.07	0.00
Subculture × Cultivar	3	0.03	0.16	0.92
Subculture × Maturity	3	0.23	1.17	0.32
Cultivar × Maturity	1	56.28	283.79	0.00
Error	147	0.20		

Table A.11 Analysis of variance for the effects of explant maturity, number of subcultures, and cultivar on the mean length of shoots/explant of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	1.02	71.65	0.00
Subculture	3	1.33	93.51	0.00
Cultivar	1	0.19	13.76	0.00
Subculture × Cultivar	3	0.01	0.63	0.06
Subculture × Maturity	3	0.07	5.10	0.00

Cultivar × Maturity	1	0.00	0.03	0.87
Error	147	0.01		

Table A.12 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, length of subculture period, and cultivar on the percentage of plantlets rooted of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	0.08	102.40	0.00
Etiolation	1	0.05	56.31	0.00
Subculture Period	1	0.02	23.90	0.00
Cultivar	1	0.03	42.35	0.00
Subculture Period × Cultivar	1	0.00	0.61	0.45
Subculture Period× Maturity	1	0.00	1.33	0.26
Subculture Period × Etiolation	1	0.01	3.15	0.09
Cultivar × Maturity	1	0.00	2.14	0.16
Cultivar × Etiolation	1	0.00	1.33	0.26
Maturity × Etiolation	1	0.00	0.28	0.60
Error	21	0.00		

Table A.13 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, length of subculture period, and cultivar on the mean number of roots/plantlet of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P

Maturity	1	132.78	167.73	0.00
Etiolation	1	67.57	85.36	0.00
Subculture Period	1	53.06	67.03	0.00
Cultivar	1	68.07	85.99	0.00
Subculture Period × Cultivar	1	1.14	1.44	0.23
Subculture Period × Maturity	1	3.84	4.85	0.03
Subculture Period × Etiolation	1	0.12	0.15	0.70
Cultivar × Maturity	1	0.27	0.35	0.56
Cultivar × Etiolation	1	0.60	0.75	0.39
Maturity × Etiolation	1	8.52	10.67	0.00
Error	515	0.80		

Table A.14 Analysis of variance for the effects of explant maturity, *in vitro* etiolation, length of subculture period, and cultivar on the mean length of roots/plantlet of micro-propagated saskatoons.

Source of Variation	DF	MS	F	P
Maturity	1	235.40	222.16	0.00
Etiolation	1	73.32	69.19	0.00
Subculture Period	1	16.54	15.61	0.01
Cultivar	1	39.11	36.91	0.00
Subculture Period × Cultivar	1	0.05	0.05	0.50
Subculture Period × Maturity	1	2.97	2.80	0.46
Subculture Period × Etiolation	1	3.95	3.72	0.35
Cultivar × Maturity	1	0.01	0.01	0.49

Cultivar × Etiolation	1	6.27	5.91	0.30
Maturity × Etiolation	1	13.58	12.82	0.03
Error	515	1.06		

Evaluation Of Disease Resistance In Saskatoon Seedlings

***** This study is incomplete due to the termination of the Native Fruit Program. Further verification of the results of the screening needs to be done, followed by field trials of more mature plants, and ultimately incorporation of this material into a breeding program.***

Background

Entomosporium leaf and berry spot is a serious disease of saskatoon. Typical disease symptoms include a defoliating leaf spot, as well as spotting, cracking and deformation of fruit (Davidson, 1989). Entomosporium leaf and berry spot has been causing significant losses to saskatoon growers since 1990, and destroyed much of the saskatoon fruit crop throughout Alberta in 1994 (Lange and Bains, 1994). Fungicidal applications of Tilt 250 EC (propiconazole) and Bravo 500 (chlorothalonil) helped to reduce leaf and berry spot on saskatoon (Lange et al., 1998). The development of saskatoon cultivars with durable disease resistance would provide a safer and more cost-effective way to control the disease.

A number of genotypes of saskatoon were evaluated for resistance to Entomosporium leaf and berry spot. These genotypes represented material selected from wild plants showing desirable characteristics, growing in the Prairie provinces and Montana. Each plant from a specific location was given an accession number, and the seed collected from the fruit of these wild plants were germinated and the resulting progeny put into tissue culture. The resulting progeny were given sub numbers, i.e. plant number 2 had at least 24 progeny, and they were labelled 2-1 to 2-24. Thus all progeny with the same first number came from one plant originally.

Methods

The procedure used to evaluate the response of the plants to Entomosporium infection was developed by Ronald and St- Pierre (2002). This procedure involved removing young leaves from the seedlings, and inoculating them with the pathogen. After an incubation period the leaves were evaluated for disease symptoms.

The saskatoon seedlings initially produced by tissue culture were transplanted into six inch (one gallon) pots. The seedlings were kept in a cold room (50C) in a dormant state until 3-4 weeks prior to testing (Figure 1). They were then placed in a growth cabinet with a 14 hour day/10 hour night cycle, day temperature of 20oC and night temperature of 16oC, to initiate leaf production (Figure 2). Young shoots were removed from the seedlings, and 16 of the youngest, expanded leaves selected for testing for resistance. The leaf petioles were placed through holes in a sheet of polystyrene floating on distilled water contained in rectangular plastic boxes (Figure 3). The leaves were excised under water to prevent air bubbles from entering the cut petioles. A total of 28 leaves, four leaves of each of seven genotypes were distributed evenly in the box. Four boxes were used in each test, the leaves in three of them were sprayed with a fungal spore suspension, and the leaves in the fourth box were sprayed with distilled water, as a control.

The spores of E. mespili were obtained from lesions produced by natural infection of bushes in 2002. Dry, infected leaves were stored at 4oC. Prior to inoculum production the leaves were moistened to encourage spore release. In order to produce a suspension containing predominantly Entomosporium spores a technique mimicking natural dispersal was developed. Individual droplets of distilled water were dropped onto lesions containing acervuli, resulting in grey masses of spores oozing out of the acervuli. These droplets of water encouraged the release of large numbers of almost exclusively Entomosporium spores, which were collected using a fine pipette. The resulting droplet suspension was diluted to produce a spore suspension of approximately 1 X 104 spores/ml. This suspension was sprayed over the leaves until individual droplets were formed on the upper surface of the leaves.

Lids were replaced on the boxes after inoculation. The boxes were then enclosed in black, plastic bags for the next 48 hours to reduce light and increase humidity in order to create conditions most favourable for infection. The leaves were incubated at 200C in the boxes for 12 days with a 14 hour day/10 hour night cycle. After the incubation period the leaves were examined for signs of infection. Typically chlorosis and/or necrosis were seen in some genotypes, as well as the production of necrotic spots with the presence of acervuli (Figure 4). Only tests in which Smoky leaves developed lesions were included in the results, to ensure that the spore suspensions used were viable, and capable of infecting a susceptible cultivar, except for the last two tests in January 2003 when there were no Smoky seedlings available. In both these tests infection occurred on almost all of the test material, indicating that the spore suspensions were viable. The reactions of the different genotypes were then compared with that of Smoky.

Of the 57 genotypes available for increase by tissue culture 26 developed sufficient seedling material for testing between October 2002 and January 2003. A minimum of two inoculation tests was carried out on these seedlings, ensuring that the percentage of leaves infected was based on the inoculation of at least 24 leaves. Observations were also made on the reaction of genotypes to mildew infection, which occurs sporadically under greenhouse conditions. Mildew developed on the leaves during some of the tests, and when this occurred the material showing resistance to mildew was noted.

The same material evaluated in the detached leaf test was also exposed to natural infection by placing two potted seedlings of each genotype in the Accession orchard from the end of May until July 29. By the end of July 100% of the Smoky leaves were infected with leaf and berry spot. The percentage of leaves infected was assessed for all exposed seedlings.

Data Collection And Statistical Analysis

The following data were collected, depending on the experiment:
Disease incidence the number of leaves, or fruit, infected with disease, expressed as a percentage.

Disease severity the % leaf area infected assessed visually, and rated according to the scale shown in the table below.

Table - Rating Scale For Severity Of *Entomosporium* Leaf Infection.

Disease severity score	% leaf area infected
0	0
0.5	<1
1	1-5
2	>5 - 10
3	>10 - 25
4	>25 - 50
5	>50 - 75
6	>75

Total yield – total weight of unsorted fruit that were harvested.
10 fruit weight – the weight of 10 of the harvested fruit selected at random.

Data were analyzed using the SAS GLM procedure. Significant treatment means were compared using the LSD test at P=0.05.

Results, Discussion and Conclusions

Levels of natural Entomosporium infections were very low in 2001 and 2002, and there was insufficient disease developed on the exposed seedlings to evaluate their response to natural inoculum, as well as insufficient disease available to obtain inoculum from for artificial screening for these years. However, data from 2003 are available.

The commercial cultivars Pearson, Smoky and Success all had over 30% of their leaves infected in the detached leaf test (Table 1). Sixteen of the 26 genotypes had fewer infected leaves than Smoky, indicating they might have resistance to the pathogen. Genotypes originating from the same wild plant had similar reactions, except for the genotype 20- , when 20-15 developed a lot less infection than 20-10 and 20-11. The genotypes A1and A3 had only slightly fewer leaves infected than Smoky and, like A2, would not be considered resistant to the pathogen. No disease developed on the uninoculated controls.

The genotypes originating from the plants labelled 2-, 9-, 13-, and 22- all had fewer than 14% leaves infected and these genotypes could provide valuable sources of disease resistance. These genotypes also showed less infection of the seedlings exposed to natural infection in most cases. However the results of natural inoculation were variable and more extensive testing of these genotypes under field conditions is necessary.

The detached leaf assay test identified a number of saskatoon genotypes that developed less leaf and berry spot infection than three of the currently grown cultivars. Further assessment of the response of these seedlings when exposed to natural infection of leaf and berry spot in the field should be monitored for at least one more season. Growth characteristics and yield data should also be considered, before producers are provided with the material. It should be noted that this study is incomplete due to the termination of the Native Fruit Program. Further verification of the results of the screening needs to be done, followed by field trials of more mature plants. Extensive testing of these genotypes under field conditions is necessary. Although this material may be resistant to Entomosporium leaf and berry spot, the genotypes may not be agronomically suitable for commercial production and ultimately, would have to be incorporated into a breeding program.

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Table 1. Response Of Saskatoon Seedling Genotypes To Artificial Inoculation Of Detached Leaves And Exposure Of Whole Seedlings To Natural Inoculum Of *E. mespili*.

Genotype number/name	**No. of inoculation tests conducted**	**% of leaves infected (average of all tests)**	**Genotypes with lower % of leaves infected than Smoky**	**% of infected leaves on seedlings exposed to natural inoculum (2 plants)**
2-10	3	8	yes	48, na*
2-24	2	4	yes	100, na
5-48	3	55	no	64,37
9-53	2	4	yes	29,71
13-31	4	6	yes	68,68
13-47	2	13	yes	79,96
14-1	3	22	yes	100,76
14-33	2	8	yes	na
14-35	3	28	yes	12,92
16-7	3	55	no	100,71
16-27	3	42	no	93,51
17-11	3	47	no	86,78
18-39	2	25	yes	41,100

20-10	3	50	no	91,71
20-11	3	55	no	93,82
20-15	2	8	yes	na
21-44	3	19	yes	41,93
21-49	2	25	yes	83,96
22-19	2	0	yes	na
24-24	2	50	no	na
29-3	2	58	no	72,70
A1	3	28	yes	100,98
A2	2	50	no	45,79
A3	2	29	yes	75,56
Meadow Lake	2	37	no	100,73
Redberry	2	21	yes	100,88
Pearson	2	37	no	100,88
Success	3	47	no	80,55
Smoky	10	32		100,100

*na means plant not available.

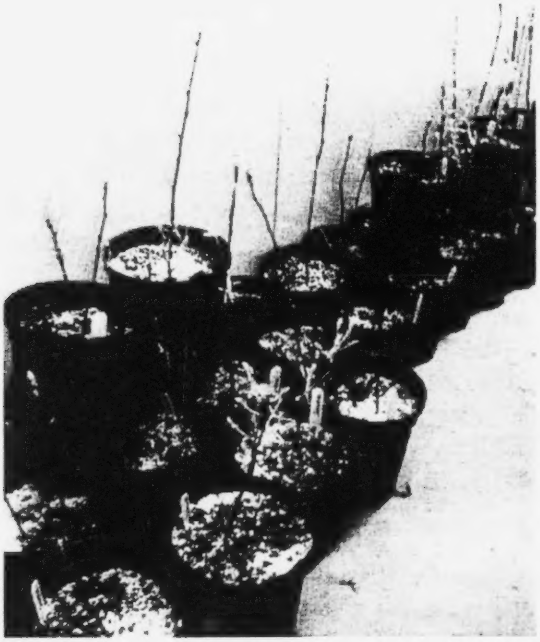

Figure 1. Potted saskatoon seedlings stored in cold room at 5°C .

Figure 2. Seedlings after approximately 4 weeks in growth cabinet have developed sufficient leaves for detached leaf testing.

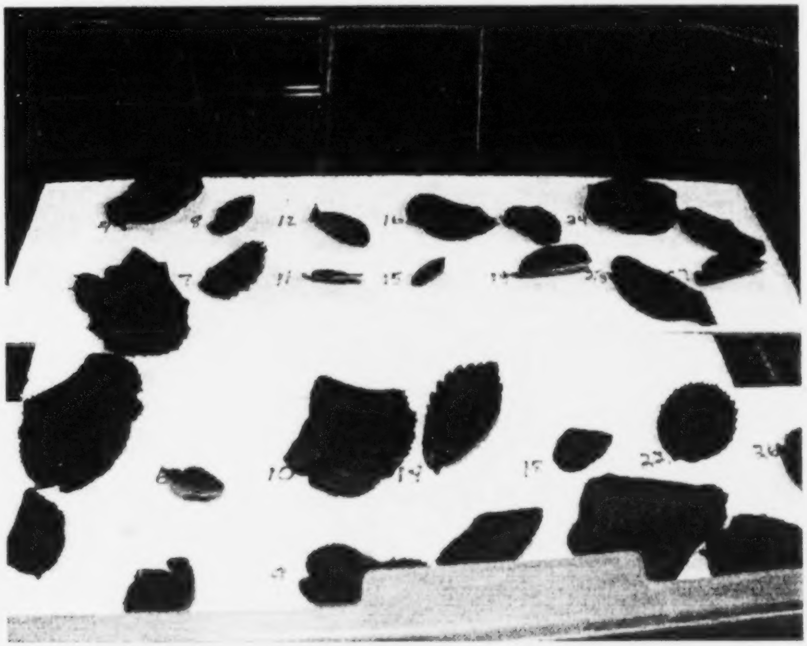

Figure 3. Detached leaves in plastic boxes, prior to inoculation with spore suspension of *E.mespili*.

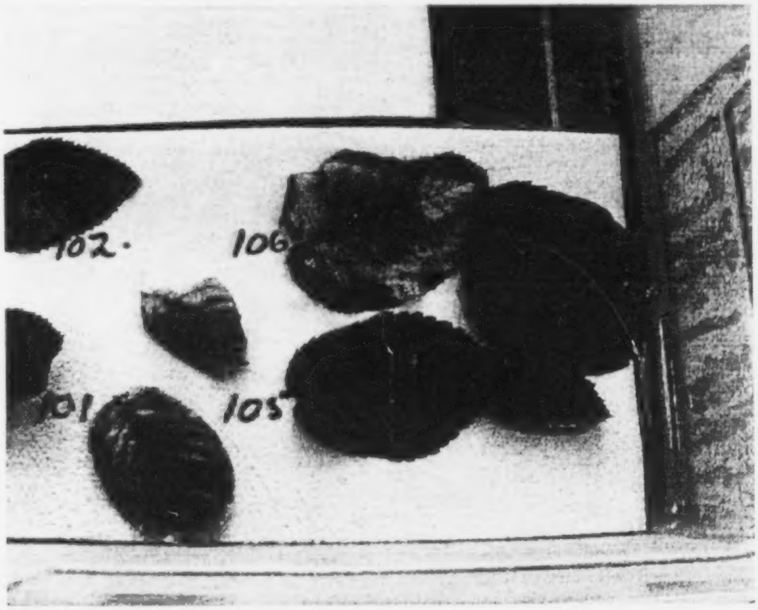

Figure 4. Inoculated leaves with dark, necrotic spots typical of infection by *E. mespili*.

3.2.2. Native Fruit Cultivar Evaluation Trials

Objectives

The objective of this activity was to evaluate native fruit cultivars for agronomic characteristics.

Deliverables

The deliverables for this activity were to include final results (primarily yield data) for the saskatoon cultivar trials at the U of S and Moonlake, and the native fruit cultivar trials at the UofS.

Results

Reports on the final results (primarily yield data) for the saskatoon cultivar trials at the U of S and Moonlake, and the native fruit cultivar trials at the UofS, follow.

Comparative Agronomic Performance of 15 Saskatoon Cultivars At Maturity

In the past, saskatoon cultivar descriptions and recommendations were based on non-replicated trials, qualitative and anecdotal information. The first extensive replicated cultivar trials of saskatoons were established by the University of Saskatchewan, Saskatoon, SK. Comparative agronomic data for saskatoon cultivars during the phase of orchard establishment are available (Zatylny et al., 2002), but comparable data for mature plants is not available. The objective of the current study was to characterize the agronomic performance of mature plants of 15 fruit-bearing cultivars of saskatoon.

Materials and Methods

The cultivar trials initially were difficult to establish because of problems with propagation and consequent lack of availability of plant material. The trial was originally established at seven sites; six of these were grower-managed sites located throughout Saskatchewan. Five of these sites were eventually excluded from the study because of site-related issues including excessive browsing by deer, lack of irrigation, excessive salinity, and poor management on the part of the co-operator. Data from the remaining two sites are presented in this paper.

Fifteen saskatoon cultivars were planted in replicated trials at the University of Saskatchewan (U of S) in Saskatoon, Saskatchewan (52°N), and at a grower-managed site approximately 15 km southwest of the city of Saskatoon (Moonlake). The trial consisted of a randomized complete block design with three blocks at each of the two sites. Each plot within a block contained five plants. The 15 cultivars tested included Bluff, Buffalo, Forestburg, Honeywood, JB30, Martin, Nelson, Northline, PAR 90, Parkhill, Pearson II, Pembina, Smoky, Success, and Thiessen. Of these, the cultivars Parkhill and Success originated in the United States, and are likely hybrids of *A. stolonifera* with *A. alnifolia* (Weir, 1995); all other cultivars are *A. alnifolia*.

One year old saskatoon plants were planted in the fall of 1991. The cultivars JB30, Pembina and Smoky were propagated from cuttings; all other cultivars were micropropagated. Plant spacing was set at 1 m within a row and 4.5 m between rows. Because of difficulties in propagation, not all cultivars were available in 1991. PAR 90 and JB30 (at both sites) and Forestburg (Moonlake) were planted in 1992; Nelson was planted at both sites in 1993. Replacement planting of plants that did not survive occurred in the spring and fall of 1992 and 1993, and in the spring of 1994.

The sites were maintained using recommended management practices (St-Pierre, 1997a). These included the use of registered pesticides to control insects, disease, and weeds. Manual weeding and cultivation were also used. Both sites were irrigated when necessary during the first four years of establishment. The U of S site was set up permanently under drip-irrigation and continued to be irrigated when necessary. The removal of diseased and damaged wood and low lying branches was conducted each year as required. Regular rejuvenation pruning of the plants involving the removal of old wood at ground level and/or thinning out of the canopy commenced in the spring of 2000 and was carried out each year as required. In general, the U of S site was managed more intensively than the Moonlake site.

Yield: Fruit were mechanically harvested in two harvests from two plants in each plot. The first harvest occurred when at least 60% of the fruit on the plants were ripe. The second harvest was done when the majority of the remaining fruit were ripe. All fruit from each sampled plant were mechanically harvested with hand-held shakers (BEI, South Haven, MI) which were raked along the branches causing the fruit to fall into catch frames below. Mechanical harvesting removed some under-ripe fruit. Immature fruit as well as any diseased, damaged or shrivelled fruit were sorted out by hand to obtain marketable yields.

Fruit Size: The number of fruit in one cup, and fruit diameter were used to measure fruit size. The number of ripe fruit required to fill a one cup measure (250 mls) was counted and recorded. Fruit diameter was measured from 30 randomly selected fruit per plot.

Evenness of Ripening: From The percentage of ripe fruit on the plants within a plot were visually assessed for ripeness based on fruit colour during the 1998, 1999 and 2000 growing seasons. The number of days that it took for the plants to go from 10% to 90% ripe fruit was calculated.

Ripening Date: The Julian date that 50% of the fruit on the plants within a plot were visually estimated to be fully ripe was recorded during the 1998, 1999 and 2000 growing seasons.

Shoot Growth: The current season's shoot growth was measured from 15 randomly selected shoots per plot from the mid-portion of the plants. Measurements were recorded in

August after shoot growth had ceased.

Data Analysis: The data were checked for normality and transformed when necessary using a square root transformation prior to statistical analysis. Back-transformed means, the transformed standard error, and the transformed overall mean are presented in the tables for data that were transformed prior to analysis. The data were analyzed using the Mixed procedure of SAS (SAS Institute Inc., Cary, NC). Sites and years were considered as random factors with blocks nested within both. Cultivar separation was accomplished by the LSMEANS (least-square means; equivalent to an LSD) option of SAS at a probability level ≤ 0.05. The GLM procedure of SAS was used to obtain the means of the random factors, and to analyze the interaction of year with site for data on fruit size.

Results and Discussion

Yield: Cultivars differed significantly in both their total and marketable yields (Table 1). The highest yielding cultivars included Bluff, Martin, Buffalo, Thiessen, JB30, Forestburg, Northline, Smoky, Honeywood, and Pearson II. Total yields and marketable yields for these cultivars ranged from 3.04 and 2.76 kg/plant for Bluff to 4.70 and 4.10 kg/plant for Pearson II, respectively. The total yields of Success and Pembina (mean = 1.34 kg/plant) were significantly lower than that of all other cultivars but Nelson. Pearson II, Honeywood, and Smoky had significantly greater marketable yields (mean = 4.14 kg/plant) than that of PAR 90, Parkhill, Nelson, Success, and Pembina (mean = 1.76 kg/plant). Pembina had a much lower percentage of marketable fruit than all the other cultivars except Success. Fruit of Pembina tended to shrivel on the plant soon after ripening, which would account for its greater percentage of unmarketable fruit.

Cultivar rankings of plant productivity from 1999-2004 were similar to the rankings of cumulative yield over the first five years of production (Zatylny et al., 2002) with the exception of Parkhill and JB30. Parkhill, a precocious producer, initially outyielded a number of the cultivars but, when mature ranked amongst the less productive cultivars. Yields of JB30 from its first five years of production were low relative to most of the other cultivars, whereas mature plants of JB30 ranked amongst the higher yielding cultivars. JB30 appears to have taken longer to get into full production, but this cultivar was also planted one year later than most of the other cultivars. Figure 1 shows that the yields of JB30 were greater in 2000 than in 1999, whereas most cultivars produced less in 2000 than in 1999.

The yield performance of Smoky, Honeywood, Forestburg and Northline in these trials agrees with previous observations of these cultivars (McConkey, 1979; St-Pierre, 1997b), however, that of Pembina does not. Pembina has been reported to be very productive (McConkey, 1979; St-Pierre, 1997b), but this study has indicated the opposite. Pembina is an older cultivar, having been introduced in 1956 (Zatylny and St-Pierre, 2003). It may be possible that the plants in this study are not the true Pembina clones, but perhaps a seedling of Pembina that unknowingly was propagated as Pembina.

The poor yields of Success and Nelson may be attributed to their small plant size. At the

U of S site in particular, the plants of these cultivars were considerably shorter than at Moonlake. Yields of these cultivars at Moonlake were 137% and 56% greater for Success and Nelson, respectively, than at the U of S (data not shown). The heavier clay soil at the U of S site may have not been suitable for growing these cultivars. The soil at Moonlake is a lighter texture (clay loam) which is more favourable for growing saskatoons. However, the yields of Nelson at the two sites did not differ significantly. Nelson also was planted two years after the other cultivars, nevertheless its yield in 2003 was less than in 1999 suggesting that it had reached its mature yield by 1999.

Typical patterns of yearly yield fluctuations from 1999-2003 are shown in Figure 1. For most cultivars, high yielding or 'on' years appear to be followed by low yielding or 'off' years, indicating a tendency towards alternate bearing. Some evidence for alternate bearing in saskatoons was also demonstrated in data on flowering collected from 2001-2003 (data not shown); the total number of flowers on the previous season's shoot growth was found to alternate from high to low to high again, matching the pattern found for total yield. The higher yielding cultivars such as Smoky, Pearson II, Honeywood and Forestburg tended to have the greatest yearly fluctuations in yield. Other cultivars such as Bluff, Buffalo, Martin, Northline, PAR 90, Pembina and JB30 experienced years of alternating high and low yields that were less extreme, similar to that of Thiessen shown in Figure 1. This alternating pattern of yearly yields did not commence until 2000 for the cultivars Bluff, Martin and JB30, indicating that the mature yields of these cultivars may not have been reached in 1999. Yearly yields of the remaining cultivars, Nelson, Parkhill and Success, did not follow this alternating pattern; the yields of these cultivars declined in 2003 from that of the previous year instead of increasing. This decline may have been the result of the annual renewal pruning that commenced three years earlier; this pruning may have set back these shorter cultivars moreso than the taller ones.

Fruit Size: Fruit size was determined by measurements of fruit diameter and the number of fruit/cup (Table 1). The cultivars fell into four different distinct categories of fruit diameters. Cultivars with the largest fruit diameters included Thiessen, Martin, PAR 90 and JB30 (mean = 13.7 mm). The fruit of Thiessen and Martin were significantly larger in diameter than JB30 by 4%. The fruit of Smoky, Nelson, Honeywood, Northline, Pearson II, and Forestburg fell into the second largest category with a mean diameter of 12.2 mm. Buffalo, Pembina and Parkhill were in the third category with a mean fruit diameter of 11.4 mm. Success and Bluff had the smallest fruit (mean diameter = 10.9 mm).

Cultivar rankings of fruit size as measured by fruit/cup were similar to that of fruit diameter but with fewer distinct differences amongst the medium-sized fruit. The fruit of Martin, Thiessen, PAR 90 and JB30 were on average almost twice the size of that of Success and Bluff. Cultivar rankings of fruit size were similar overall to that found in previous years of this trial (Zatylny et al., 2002).

It is worthwhile to note that fruit size was smaller in the years 2001 and 2002 (Figure 2). These two years were very dry years with below average precipitation. Fruit size was reduced to a greater extent at Moonlake. The U of S orchard was irrigated regularly, however, the Moonlake site did not have a permanent irrigation set up and was not irrigated on a regular basis. Statisical analysis accomplished by Proc GLM to examine the interaction of year and site for these parameters indicated that fruit size measured as fruit/cup and diameter was significantly smaller at Moonlake in 2001 and 2002 than at the U of S site, and that of all other years at both sites. These results emphasize the importance of adequate irrigation in ensure optimum fruit size is achieved particularly during years of drought.

Evenness of Ripening: Evenness of ripening of fruit on a plant is a desirable trait when mechanical harvesters are used in order to enable a once-over harvest. However, no consistent differences existed among the cultivars in evenness of ripening as recorded as the number of days required for the plants to go from 10% to 90% ripe fruit (Table 1). Variability was large from year to year and between the sites. On average, it took approximately two weeks from the onset of ripening to completion.

Ripening Date: The cultivars differed in their harvest dates as measured as the Julian day that 50% of the fruit on a plant were fully ripe (Table 1). Fruit of the cultivars PAR 90, JB30, Thiessen, Success, Martin and Honeywood matured 4-7 days earlier than that of Northline, Parkhill, Buffalo and Nelson. Fruit of Pembina ripened significantly later than that of all of the other cultivars by 6-13 days.

Shoot Growth: Shoot growth differed significantly among the cultivars (Table 1). Annual shoot growth was significantly greater for the cultivars JB30, PAR 90 and Thiessen (mean = 19.4 cm) than that of Honeywood, Pembina, Smoky, Pearson II and Parkhill (mean = 13.0 cm). The remaining cultivars were intermediate in their shoot growth ranging from 14.8 cm to 17.6 cm. The relative amount of shoot growth amongst the cultivars changed dramatically from previous years for some of the cultivars but not for others. In 1994, Pearson II and Smoky had a large amount of shoot growth similar to that of Thiessen and Martin (Zatylny et al., 2002), but from 1999-2003 had significantly less shoot growth than these cultivars. In general, the shoot growth of the cultivars has decreased over the last five years as the plants approach their mature size (Figure 3).

Conclusions

This study enabled the quantitative characterization and direct comparison of 15 mature saskatoon cultivars from replicated trials at two sites over five years. Previously, data from replicated trials was not available for mature plants of these cultivars. Such information is directly valuable to the grower. High yielding cultivars with good fruit size are important for the commercial production of saskatoons. An orchard of cultivars with different harvest times are beneficial in extending the harvest period. Of the cultivars tested, those with high yields and a large fruit size included JB30, Thiessen and Martin. Pearson II, Honeywood, Smoky, Northline and Forestburg had high yields and medium-sized fruit. Pearson II, Honeywood and Smoky tended to have the highest fruit yields among these cultivars although not significantly different, but also had a greater tendency towards alternate bearing. Of these cultivars, JB30, Thiessen, Martin and Honeywood fruited earlier than Northline.

Many other factors need to be considered when choosing a cultivar for production: these include disease and insect resistance, suckering, blossoming time, post-harvest storage and fresh fruit quality. Data on some of these characteristics have been previously published (Zatylny et al., 2002; Ronald, 2001), however more cultivar screening needs to be done in the area of insect and disease resistance. Future research should also examine differences in the fresh fruit storageability of the cultivars.

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Table 1. Agronomic characteristics of 15 saskatoon cultivars from 1999 to 2003 grown at two sites in Saskatchewan, the U of S and Moonlake.

Cultivar	Total Yield (kg/plant)	Marketable Yield (kg/plant)	Fruit Diameter (mm)	Number of Fruit/Cup	Days from 10 to 90% Ripe Fruit[1]	Julian Days to 50% Ripe Fruit[1]	Shoot Growth (cm)
Bluff	3.04 bcde[2]	2.76 cde	10.9 a	236 e	11.5	200.5 bcde	16.9 cde
Buffalo	3.86 cde	3.18 cde	11.4 b	186 cd	14.8	201.7 de	14.8 bcde
Forestburg	4.09 cde	3.72 de	12.4 c	165 b	14.3	197.8 abc	15.6 bcde
Honeywood	4.67 e	4.16 e	12.1 c	173 bcd	13.8	197.4 ab	14.2 bcd
JB30	3.97 cde	3.62 de	13.3 d	126 a	14	197.0 ab	21.4 f
Martin	3.25 bcde	2.88 cde	13.8 e	111 a	14.4	197.4 ab	17.6 def
Nelson	2.14 ab	1.88 bc	12.1 c	167 bc	15.4	203.4 e	15.2 bcde
Northline	4.14 cde	3.74 de	12.2 c	168 bcd	13.3	201.1 cde	15.0 bcde
PAR 90	2.78 bcd	2.49 cd	13.7 de	112 a	13.2	196.2 a	18.5 ef
Parkhill	2.73 bc	2.46 cd	11.5 b	188 d	15.4	201.3 cde	10.5 a
Pearson II	4.70 e	4.16 e	12.2 c	169 bcd	13.9	198.4 abcd	13.0 ab
Pembina	1.36 a	0.72 a	11.4 b	182 bcd	11.8	209.3 f	14.2 bcd
Smoky	4.58 de	4.10 e	12.1 c	172 bcd	15	198.1 abcd	13.3 abc
Success	1.32 a	1.23 ab	10.8 a	214 e	11.8	197.1 ab	N/A[3]
Thiessen	3.94 cde	3.56 de	13.9 e	111 a	14	197.0 ab	18.5 ef
Mean	(1.81)[4]	(1.69)	12.3	(12.78)	13.8	199.6	(3.94)
S.E.[5]	(0.216)	(0.201)	0.197	(0.435)	1.87	1.50	(0.574)

[1] Data from 1999 and 2000 only.

[2] Means within a column followed by the same letter are not significantly different ($P \leq 0.05$).

[3] Data not available.

[4] The transformed mean and transformed standard error are presented in brackets when the data were transformed prior to analysis.

[5] Standard error of the mean.

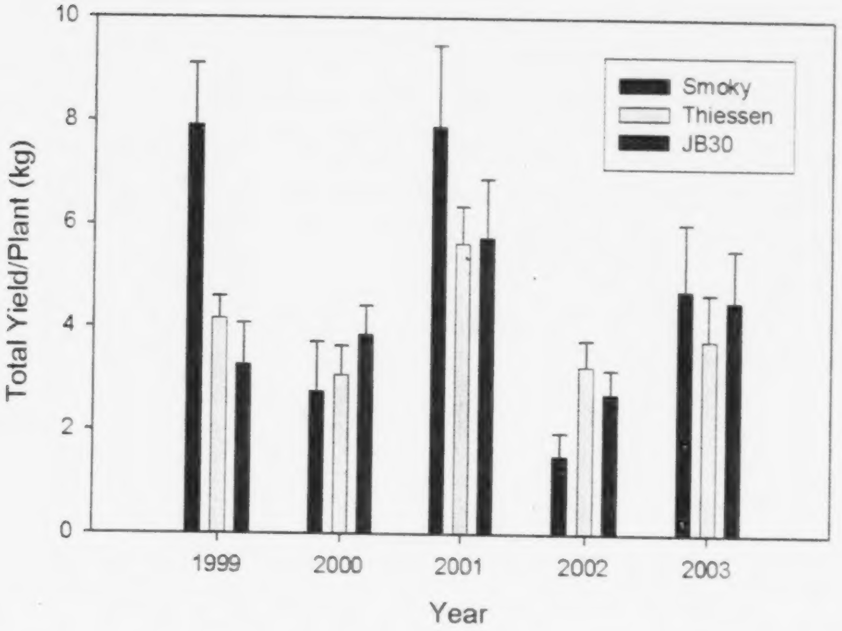

Figure 1. Three representative patterns of yearly fluctuations in yield of the saskatoon cultivars grown at the U of S and at Moonlake from 1999 to 2003.

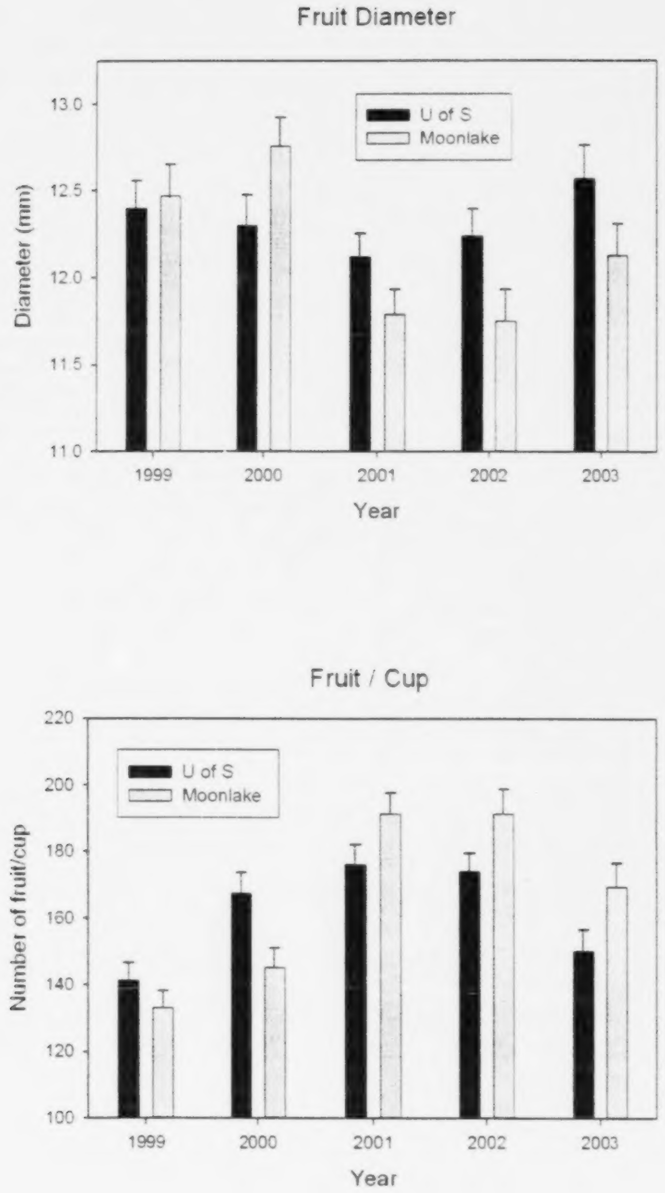

Figure 2. Mean fruit diameter and fruit/cup of 15 saskatoon cultivars at the U of S and Moonlake from 1999 to 2003.

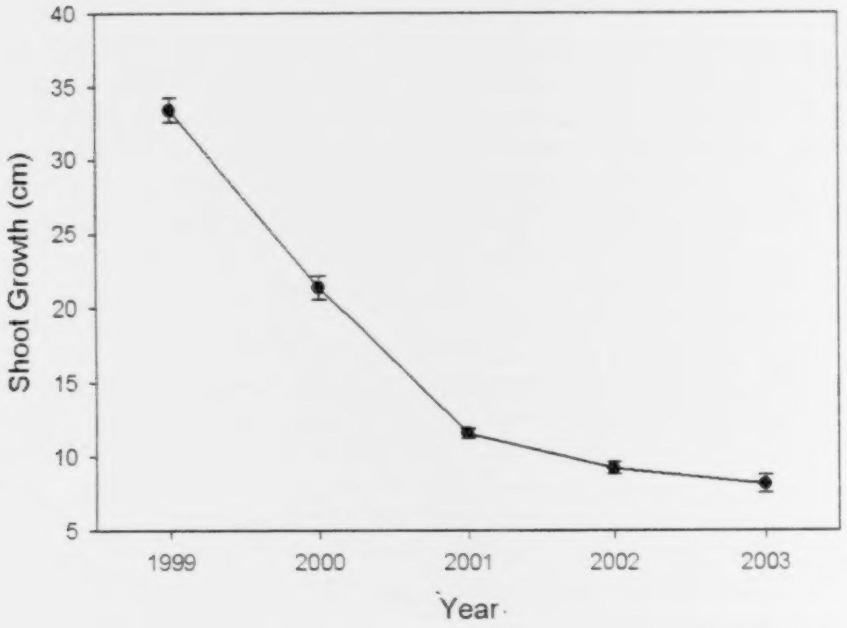

Figure 3. Average shoot growth per year of 15 saskatoon cultivars grown at the U of S and Moonlake from 1999 to 2003.

The agronomic performance of chokecherry, pincherry, highbush cranberry and black currant cultivars evaluated in Saskatchewan

Background

The objective of this study was to evaluate selected cultivars of chokecherry, pincherry, highbush cranberry and black currant for their agronomic characteristics. This research will provide a basis upon which the agronomic characteristics of any new selections may be compared, and from which growers can choose cultivars for production. Cultivars of these native fruits have never been evaluated in replicated cultivar trials, and all previous information has been obtained from observational or unreplicated data. Likewise, black currant cultivar recommendations for the prairies have been primarily based on their ability to overwinter. Thus, the University of Saskatchewan has established replicated cultivar trials of these fruits for evaluation as potential new horticultural crops for the prairies.

Materials and Methods

Cultivar evaluation trials of chokecherry, pincherry, highbush cranberry and black currants were established at two sites in Saskatchewan, at Saskatoon within the University of Saskatchewan field plots, and at Outlook. These trials consisted of three blocks in a completely randomized design at each site. Five plants per cultivar were planted in each block. All plants were propagated by cuttings or tissue culture and planted as one year old plants. The plants were planted at spacings of 1 m within the rows and 3 m and 4.5 m between the rows for black currants and the other native fruits, respectively.

Chokecherry cultivars evaluated included BoughenYellow, Copper Schubert, Garrington, Goertz, Lee Red, Mission Red, Robert and Espenant, a selection from a grower near Hudson Bay, SK. Only Boughen Yellow, Garrington and Lee Red were planted at Outlook. All cultivars were planted in the fall of 1994 at both sites except Copper Schubert, Mission Red, and Espenant which were planted in the fall of 1995.

Pincherry cultivars evaluated at both sites included Jumping Pound, Lee #4, and Mary Liss. All were planted in the fall of 1994.

Highbush cranberry cultivars evaluated included Alaska, Andrews, Garry Pink, Manitou, Phillips, Wentworth and Espenant, a selection from a grower near Hudson Bay, SK. Only Alaska, Phillips, and Wentworth were planted at Outlook. All highbush cranberry cultivars were planted in the fall of 1994 except for Espenant, which was planted in the fall of the following year.

Two black currant cultivar trials were established at Saskatoon. Black currant cultivars evaluated in the first trial included Boskoop Giant, Consort, Coronet, Crusader, Magnus, Topsy, Wellington, Willoughby, and three open-pollinated selections of Öjebyn from the University of Saskatchewan (5-24-9, 5-23-42 and 25-23-23). The cultivars Consort, Wellington and Willoughby were planted at Outlook. These cultivars were planted in the fall of 1994 at both sites. A second black currant trial was established at Saskatoon in the spring of 1998. Black currant cultivars in this trial included Ben Alder, Ben Lomond, Ben Nevis, Ben Sarek, Consort, Crusader, Magnus, McGinnis, Noir de Bourgogne, Titania, Wellington, and an open-pollinated selection of Öjebyn from the University of Saskatchewan (4-24-29). McGinnis Black is a selection from the SCRI breeding program that was named and propagated by McGinnis Berry Crops nursery in BC?

The trials were irrigated by drip irrigation. All weeds were controlled manually and by cultivation. Leaf roller caterpillars in chokecherries and black currants were controlled by insecticides in 2000 and 2001. Fruit were manually harvested from one to three plants per cultivar from each replicate. The currant season's shoot growth were recorded in late summer from five randomly selected shoots from each of the three middle plants within a plot. The number of new suckers per plant from the three middle plants within a plot were recorded for chokecherries in 1999-2001.

Cultivar data were analysed using SAS Proc Mixed (SAS Institute, Cary, NC) in which site and year were considered to be random factors. Data were checked for normality prior to statistical analysis and transformed if necessary by square root. Cultivar mean separation was accomplished by LSD.

Results and Discussion

Chokecherry

The chokecherry plants did not produce significant amounts of fruit until 1999, however, the cultivars Boughen Yellow and Garrington appeared to be more precocious and produced some fruit in 1998 at both sites (mean yield = 0.43 and 0.19 kg/plant for Boughen Yellow and Garrington, respectively). The chokecherry plants appeared to have reached their mature yielding capacity by 2002 as indicated by the lack of a further yield increase in 2003 (Figure 1). At Saskatoon from 2000-2003, Espenant was the highest yielding of the cultivars followed by that of Garrington, Lee Red and Boughen Yellow. Espenant yielded 1.9 to 2.8 times more fruit than that of Copper Schubert, Goertz, Mission Red, and Robert (Table 1). The three chokecherry cultivars at Outlook did not differ in their yield.

Fruit size differed among the cultivars at both sites (Table 1). At Saskatoon, Mission Red had significantly smaller fruit than all the other cultivars; Goertz had significantly larger fruit by 18-35% than Garrington, Boughen Yellow and Mission Red. At Outlook, the fruit of Boughen Yellow were significantly smaller than that of Garrington and Lee Red by 17-38%.

Differences in shoot growth were found amongst the cultivars at Saskatoon, but not at Outlook. At Saskatoon, Copper Schubert had 23-53% greater shoot growth than all of the other cultivars (Table 1). Robert also had a greater shoot growth than Garrington at this site. Yearly shoot growth decreased as the plants matured (Figure 2). Sucker production did not differ among the chokecherry cultivars at either site. An average of 1.4 and 2.6 suckers/chokecherry plant were produced at Saskatoon and Outlook, respectively, from 1999-2001 (data not shown).

Pincherry

Pincherry yield differed among the three cultivars. At both sites, Lee #4 yielded twice as much or more than that of Mary Liss or Jumping Pound (Table 2). The pincherries at Saskatoon were more precocious, producing 9% of their mature yield in1997, and 16% in 1998, whereas pincherry fruit yields at Outlook in these two years were not worth harvesting. The maximum yield of pincherry occurred in 1999 (Figure 1). Fruit size or shoot growth did not differ significantly among the cultivars at both sites.

Highbush Cranberry

A few of the highbush cranberry cultivars produced fruit in 1999; these included Alaska, Garry Pink, Manitou, and Wentworth (Mean yield = 1.56 kg/plant). No further increase in yearly yields of highbush cranberry occurred after 2002, possibly indicating that its mature yields had been attained (Figure 1). Of the highbush cranberry cultivars, Phillips at both sites was never harvested due to bearing almost no fruit. The cultivar Andrews at Saskatoon also yielded very little fruit; it was only harvested in 1999 and 2000 (mean yield = 0.37 kg/plant), and therefore, was not included in the statistical analysis. The poor fruit yield of Andrews could be attributed, in part, to extensive mite damage that occurred on this cultivar. At Saskatoon, Garry Pink, Wentworth and Manitou yielded 1.8 to 2 times more fruit than Espenant (Table 3). At Outlook, the highbush cranberry cultivar, Wentworth yielded 35% more fruit than that of Alaska, whereas at Saskatoon, the yields of these two cultivars did not differ significantly.

Cultivars differed in fruit size at Saskatoon with Espenant having the significantly smallest fruit of all the cultivars (Table 3). Manitou had significantly larger fruit than Wentworth, Garry Pink and Espenant at this site. Manitou was originally selected from wild stands in Manitoba for its large fruit size (Darrow, 1975). The fruit size of Wentworth and Alaska did not differ at Outlook, nor at Saskatoon.

Yearly shoot growth did not differ among the cultivars at Outlook, however at Saskatoon, the shoot growth of Manitou was 26 and 50% greater than that of Espenant and Andrews, respectively (Table 3).

Black Currant

Trial 1

The first black currant cultivar trial came into production in 1999. Although the cultivars at Outlook produced significant amounts of fruit in 1998 (mean yield = 0.48 kg/plant), negligible amounts of fruit were produced at Saskatoon that year. Cultivar differences in yield from 1999-2002 were found at Saskatoon but not at Outlook (Table 4). At Saskatoon, Boskoop Giant yielded enough fruit (mean yield = 0.36 kg/plant) to be harvested in 2000, however it was not harvested in any of the other years due to its very low fruit production and so was not included in the statistical analysis. At Saskatoon, Consort, 5-23-42 and Wellington produced on average 3.8 times significantly greater yields than 5-24-9 and Willoughby. The yields of Consort, Wellington and Willoughby did not differ significantly at Outlook. At Saskatoon, Willoughby yielded significantly less than Wellington, but the yield of these two cultivars was not significantly different at Outlook. Nevertheless, at Outlook, Wellington yielded almost 3 times more fruit than Willoughby; this difference was probably not significant due to the small experimental size at this site.

Fruit size differed greatly from year to year. For example, Wellington from one plot at Saskatoon had 108 fruit per cup in 1999, but 446 fruit per cup in 2002. Fruit size differed significantly at both sites (Table 4). At Outlook over the four years, the fruit size of Wellington, Willoughby and Consort all differed from each other with Wellington having the largest fruit and Consort, the smallest. The cultivars at Saskatoon with the largest fruit size included 5-23-42, 25-23-23, Wellington, 5-24-9, and Topsy (mean = 225 fruit/cup). Fruit size of the selections 5-23-42 and 25-23-23 was significantly larger than that of Consort, Coronet, and Crusader by 71%. Although the number of fruit/cup differed between Wellington and Consort at Outlook, these two cultivars did not differ in fruit size at Saskatoon.

Average yearly shoot growth over the four years did not differ among the cultivars at Saskatoon nor at Outlook, but decreased as the plants matured (Figure 2). Mean shoot growth at Saskatoon and at Outlook were 19.4 cm and 18.2 cm, respectively from 1999-2002.

Trial 2:

The black currant cultivars in the second trial did not produce significant quantities of fruit until 2000. However, the more precocious of the cultivars did produce some fruit in 1999. These cultivars included Ben Alder, Ben Nevis, Ben Sarek, and McGinnis Black. Ben Nevis yielded an average of 0.64 kg/plant that year while the other cultivars produced an average of 0.13 kg/plant. The black currant cultivars in the second trial established at Saskatoon differed significantly in their yield (Table 5). The cultivars McGinnis Black and Ben Nevis (mean yield = 1.87 kg/plant) had significantly greater yields than 4-24-29, Noir de Bourgogne, Titania, Magnus, Crusader, Consort, and Wellington (mean yield = 1.18 kg/plant). The Scottish 'Ben' types have outyielded a number of other black currant cultivars in previous studies (Muster and Roser, 1993; Dale et al., 1993). Titania has produced high yields comparable to that of the 'Ben' types in yield trials in Poland and Norway (Pluta and Zurawicz, 1993; Nes, 1993; Muster and Roser, 1993; Pluta et al, 1993). However, in this study Titania produced 30-45% less fruit than the 'Ben' types in these trials.

Ben Sarek and McGinnis Black had the largest fruit size (mean = 145 fruit/cup) followed by that of Ben Alder, Ben Nevis, Wellington and Titania (mean = 183 fruit/cup) all which did not differ significantly from that of McGinnis Black (Table 5). Consort, Crusader and Noir de Bourgogne were among the smallest fruiting of the cultivars (mean = 269 fruit/cup).

Yearly shoot growth did not differ significantly among the cultivars (data not shown). Mean shoot growth from 2001-2003 of the cultivars in this second trial was 25.3 cm.

Black currants cultivars in both trials experienced large yearly fluctuations in yield (Figure 2). The highest yields occurred in 1999 for the first trial and in 2003 for the second trial.

Years of below-normal yields were most likely due to premature fruit drop. This condition can occur approximately 3 weeks after flowering and can cause major yield losses in black currant (Brennan, 1990). Unfavourable environmental conditions, such as low but above zero temperatures during flowering (Dale, 1984) can increase premature fruit drop. The cultivar Magnus in particular has been reported to be very susceptible to premature fruit drop due to low temperatures during flowering (Dale, 1984). This however, does not explain the yearly variations in yield in this study as yields were high in 2003 in spite of temperatures being quite cool during the week that the black currants blossomed that spring. Although other factors have been implicated to increase premature fruit drop, such as insufficient fertilization and post-harvest drought in the previous season, there is no direct evidence to support this relationship (Brennan, 1990). In this study, there was also no association with post-harvest moisture conditions and yield in the following season. In general, black currants prefer cool, moist conditions (Barney, 1996). The spring of 1999, a high-yielding year, was cooler than normal with above average rainfall, which may account for the higher yields obtained in this year. However, cool and moist conditions did not account for the high yields in 2003 which experienced above average temperatures and below average rainfall in spring. It is possible that black currants in the second trial could have been just coming into full production in 2003 which may have accounted for its higher yields in this year compared to previous years. Nevertheless, it appears that the conditions that dictate a high yielding year for black currants are complex and not solely a factor of spring weather conditions.

Conclusions

A number of the native fruit cultivars evaluated in this study proved to be superior in yielding capacity and/or fruit size. This information was not previously available and will provide a basis for cultivar selection of these fruits by growers. Of the chokecherry cultivars evaluated, the high yielding capacity of the selection, Espenant, warrants further attention. Garrington and Lee Red also proved to be more productive of the chokecherry cultivars. The large fruit size of Goertz makes this chokecherry cultivar attractive for both fresh consumption and processing. Of the pincherry cultivars evaluated, Lee #4 stood out as being very productive. The highbush cranberry cultivars, Garry Pink, Wentworth and Manitou produced good yields. Of these three, Manitou also had large fruit.

Of the black currants cultivars evaluated, McGinnis Black, Ben Nevis, Wellington and the selection 5-23-42 were high yielding with large fruit. However, black currant production in Saskatchewan will probably always be highly variable producing inconsistent and often poor yields due to the unsuitable climate. Until the breeding and selection of black currants that can better tolerate the prairie climate, commercial production of black currants in Saskatchewan may not be feasible.

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Table 1. Mean fruit yield, fruit size and shoot growth of chokecherry cultivars grown at Saskatoon and Outlook from 2000-2003.

Cultivar	Saskatoon			Outlook		
	Yield (kg/plant)	Number of Fruit per Cup	Shoot Growth (cm)	Yield (kg/plant)	Number of Fruit per Cup	Shoot Growth (cm)
Boughen Yellow	4.95 abcd[1]	245 c	24.0 ab	3.7	287 a	20.5
Copper Schubert	3.72 abc	214 abc	34.3 c			
Espenant	7.17 d	229 abc	26.7 ab			
Garrington	5.92 cd	238 bc	22.4 a	5.01	256 a	21.3
Goertz	3.32 ab	194 a	25.9 ab			
Lee Red	5.12 abcd	203 ab	25.6 ab	4.45	208 a	22.6
Mission Red	2.91 ab	299 d	24.4 ab			
Robert	2.58 a	211 abc	27.9 b			
Standard Error	0.939	13.1	9.08	1.283	20.8	3.13

[1] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 2. Mean fruit yield and fruit size of pincherry cultivars from 1999-2003 at Saskatoon and 1999-2002 at Outlook.

Cultivar	Saskatoon		Outlook	
	Yield (kg/plant)	Number of Fruit per Cup	Yield (kg/plant)	Number of Fruit per Cup
Jumping Pound	1.55 a[1]	229	1.35 a	276
Lee #4	3.08 b	224	3.13 b	259
Mary Liss	1.56 a	238	1.15 a	NA[2]
Standard Error	0.237	24.5	0.672	31.4

[1] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

[2] Data not available.

Table 3. Mean fruit yield, fruit size and shoot growth of highbush cranberry cultivars grown at Saskatoon and Outlook from 2000-2003.

Cultivar	Saskatoon			Outlook		
	Yield (kg/plant)	Number of Fruit per Cup	Shoot Growth (cm)	Yield (kg/plant)	Number of Fruit per Cup	Shoot Growth (cm)
Alaska	1.67 ab[1]	222 ab	32.5 bc	0.79 a	263	33.4
Andrews	NA[2]	NA	24.2 a			
Espenant	1.02 a	310 c	29.0 ab			
Garry Pink	2.07 b	252 b	32.4 bc			
Manitou	1.92 b	212 a	36.4 c			
Phillips	NA	NA	32.1 bc	NA	NA	37.8
Wentworth	2.04 b	247 b	30.7 abc	1.07 b	281	33.2
Standard Error	0.277	15.1	3.88	0.209	32.7	4.88

[1] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

[2] Data not available.

Table 4. Mean fruit yield and fruit size of black currant cultivars (Trial 1) at Saskatoon and Outlook from 1999-2002.

Cultivar	Saskatoon		Outlook	
	Yield (kg/plant)	Number of Fruit per Cup	Yield (kg/plant)	Number of Fruit per Cup
39956	0.29 ab	248 abcd		
15483	0.95 c	187 a		
25-23-23	0.54 bc	189 ab		
Consort	0.99 c	304 cde	1.31	352 c
Coronet	0.62 bc	319 de		
Crusader	0.62 bc	341 e		
Magnus	0.61 bc	264 bcd		
Topsy	0.59 bc	261 abcd		
Wellington	0.94 c	239 abc	1.52	220 a
Willoughby	0.21 a	NA[2]	0.53	283 b
Standard Error	-0.236	56.6	0.633	19.4

[1] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

[2] Data not available.

Table 5. Mean fruit yield and fruit size of black currant cultivars (Trial 2) at Saskatoon from 2000-2003.

Cultivar	Yield (kg/plant)	Number of Fruit per Cup
47231	0.21 a[1]	202 cd
Ben Alder	1.14 bc	178 abc
Ben Lomond	1.11 bc	199 cd
Ben Nevis	1.74 c	180 bc
Ben Sarek	1.30 bc	138 a
Consort	0.54 ab	284 f
Crusader	0.54 ab	265 ef
Magnus	0.54 ab	236 de
McGinnis Black	2.00 c	152 ab
Noir de Bourgogne	0.30 a	257 ef
Titania	0.52 ab	190 bc
Wellington	0.66 ab	182 bc
Standard Error	(0.278)[2]	26.1

[1] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

[2] The transformed standard error is presented in brackets when data were transformed prior to analysis. Backtransformed means are presented.

3.2.3. Understanding Growth, Development & Yield Production In Native Fruit Species

Objectives

The objective of this activity was to determine what factors influence the survival, successful establishment, and growth, vigour, volume and consistency of yield, and fruit quality of native fruit species so as to provide knowledge for the development of improved management practices.

Deliverables

Deliverables for this activity were to include the final results for the transplant, pruning and propagation method studies.

Results

Reports on the final results for the transplant, pruning and propagation method studies follow. It is important to note that the last two of these studies are incomplete due to the termination of the Native Fruit Development Program. Two to four more years of data would be required to adequately assess the results of the experimental treatments applied in terms of yield in particular.

The effect of soil mulch and planting date on the survival and field establishment of saskatoon transplants

Background

Little research has been done on the orchard management practices of the saskatoon. Knowledge of what factors influence the survival, successful establishment, growth and vigour of saskatoons is limited. Poor survival and establishment in the field is a frequent problem.

The use of soil mulches has been reported to increase the growth and establishment of newly planted orchards (Foshee et al., 1996; Måge, 1982; Måge and Skogerbo, 1992; Smith et al., 2000; White and Holloway, 1967). Mulches act primarily by suppressing weed growth, and conserving soil moisture through reduced evaporation (Hogue and Neilsen, 1987; Robinson, 1988). Mulches also modify the soil thermal microclimate. Organic mulches insulate the soil from high summer temperatures, whereas black plastic mulch increases soil temperatures (Ashworth and Harrison, 1983; Hartley and Rahman, 1997; Liakatas et al., 1986; Måge, 1982; Parfitt and Stott, 1984). In this study, the effect of black plastic and wood chip soil mulches on saskatoon plant growth and establishment in the field was examined.

Young saskatoon plants are often received from many propagators as actively growing plants anytime between May to September. The timing of transplanting of these non-dormant plants to the field can be crucial to ensure their optimum survival and establishment. Furthermore, confusing and conflicting recommendations as to when to transplant have been received from propagators and extension personnel. In this study, five transplanting dates of non-dormant saskatoon plants were investigated for their effect on plant growth and survival.

Materials and Methods

This study was conducted at three sites in Saskatchewan: Saskatoon, Keeler and Outlook. Treatments included five transplanting dates (each month from late-May to late-September) and three mulch treatments (unmulched control, black plastic, and wood chips). The experiment was set up as a randomized complete block design with three replicates at each site. Experiments at Saskatoon and Keeler were planted in 1999 with four plants within a plot. The Outlook study was established in 1998; at this site only two mulch treatments were used (no mulch and black plastic) and each plot consisted of five plants. Plants at Saskatoon and Outlook were planted with 0.75 m between plants within a plot, 1.75 m between plots and 3 m between rows. Row spacing at Keeler, a grower-managed site, was increased to 5 m to match the existing row spacing in the rest of the orchard.

Micropropagated plants of the cultivar Smoky were used for the study. Plants were received as non-dormant plants in small pots or Root Trainers©. Transplanting dates were late-May, late-June, late-July, late-August, and late-September. Plant material for the last four plantings was transplanted into 3.8 L pots in Sunshine mix #4 potting medium. The medium was amended with 2.5g/L of Plant Products Nutricote 18-6-8 type 70 time-release fertilizer to avoid nutrient deficiencies during the growing season. Potted plants were grown in a shade house until planted in the field.

The mulch treatments included a bare-soil control (no mulch), black plastic (2.7 mil) and poplar wood chips. The black plastic mulch was manually laid over the saskatoon transplants. Holes were then cut in the mulch and the plant shoots were carefully pulled through the plastic. Plants receiving the wood chip mulch treatment were transplanted into a shallow trench and then covered with approximately 20 cm of wood chips.

All sites were drip irrigated. Drip irrigation lines were laid prior to mulching under the black plastic and wood chip mulch. Orthene was applied at the study sites to control woolly elm aphid infestations. Weeds were controlled both manually and mechanically at all sites.

Meteorological data were recorded at Saskatoon in 2000 and 2001 and at Keeler in 2000 using Spectrum Technologies, Inc. Model 450 WatchDog^{TM} dataloggers. Data were recorded hourly. Soil moisture and temperature were measured at 15 and 30 cm depths. Air temperature and humidity were recorded at a 1 m height within the orchard.

Data on plant growth and survival were collected for the first two years after planting. Plant survival was recorded as the percentage of plants surviving at the end of the growing season. Plant height was measured as the distance from the soil level to the tallest shoot tip; this measurement was taken from the original transplant only and not from suckers. Yearly shoot growth was measured from the main stem of the transplant. The number of first order branches on the main stem of the transplant were counted. The average number of suckers per plant and average sucker length per plant were also recorded.

At the end of the 2000 growing season at the Outlook site, and at the end of the 2001 growing season at the Saskatoon and Keeler sites, plants were undercut and harvested. At this time, fall survival and shoot biomass data were collected. It was not possible to harvest the roots successfully and therefore root biomass data were not collected. The oven dry weight of the above-ground biomass was reported as the shoot dry weight per plant. Plot shoot dry weight was determined by multiplying the average shoot dry weight per plant by the number of surviving plants within the plot.

Plot means were used in the data analysis. Data were analyzed by analysis of variance using the GLM procedure of SAS (SAS Institute Inc., Cary, NC). Data were checked for normality and transformed prior to analysis when necessary using the square root $(x + 0.5)$ transformation. Back-transformed data are presented in the tables. Mean separation was accomplished by a Fisher's LSD test using the LSMEANS option of SAS.

Results and Discussion

The three sites differed greatly in the survival and growth of the transplants (Tables 1-6). Plants by far had the best survival and were the most vigorous at the Outlook site. There may be a number of factors contributing to this. First, plants used at Outlook were obtained from a different propagator and were more vigourous from the start. Second, the soil at Outlook is light in texture and better drained, characteristics that enhance growth of saskatoons (St-Pierre, 1997). The Saskatoon site had a heavy clay soil; saskatoon plants at this site traditionally have less vigorous growth and are shorter than plants on sites with a lighter soil texture. The soil at Keeler is a clay loam which is more desirable than a heavy clay soil, however, this site was very exposed, windy, and suffered from extensive rodent damage. Keeler was also a grower-managed site in which standard management practices were not closely followed; weed control was poor and irrigation was inconsistent. Consequently, survival and growth was much lower at Keeler than at the other two sites due to the combined stresses that existed there. Because transplants at Keeler received inconsistent care from the grower following the different transplant dates, this site was examined separately from the Saskatoon site and thus, these two sites were not combined together in the data analysis.

Mulch treatments influenced both growth and survival of the transplants at Saskatoon and Keeler, but had little affect at the Outlook site. The effect of the mulch treatments was more apparent in the second year after planting (2001). In the first year following planting, mulch treatments only had a significant effect on plant survival, sucker number and average sucker length at Saskatoon, and on plant survival, height, and branch number at Keeler. In the second year, plant survival and all measurements of growth except shoot and plot dry weights were affected by the mulch treatments at Saskatoon. At Keeler in the second year, plant height, branch number, average sucker length, and shoot dry weight were significantly influenced by the mulch treatments. At Outlook in the second year after planting, only branch and sucker number were significantly affected by the mulch treatments.

Survival of plants grown using plastic mulch was lower than for plants mulched with wood chips. In both years at Saskatoon, survival was on average 30% less for plants grown using plastic mulch than wood chips (Tables 1 and 2). At Keeler, plants in wood chips had a 45% greater survival than those mulched with plastic in 2000; this trend was also apparent in 2001 although not quite significant (Tables 3 and 4). Although plants grown with plastic mulch had a lower survival than unmulched plants, this decrease was not significant except at the Saskatoon site in 2001. Differences in survival were not apparent at Outlook between plants in plastic mulch and bare soil (Table 5). Survival may have been decreased for plants mulched with plastic due to the damage that may have occurred during the application of the mulch over the plants and then by the process of pulling the plants through the plastic. In addition, sunscald was noted on a number of transplants mulched with plastic following the first winter. This winter damage may have been caused by poor fall acclimatization of the plants mulched with plastic due to the higher soil temperatures recorded under the plastic in the fall (data not shown). Blueberries grown in Estonia with plastic mulch were also reported to suffer from a greater winter injury than plants in organic mulch or those unmulched because these plants continued to grow into the fall (Starast et al., 2002).

Although survival was reduced, growth tended to be greater for plants grown using plastic mulch at Saskatoon and Keeler; at Outlook, growth was not enhanced by plastic mulch other than branch number. This may be associated with the fact that the plants at Outlook were very vigorous to start with. In addition, the climate at Outlook in the year of planting was much warmer than at Saskatoon and Keeler, which were planted a year later. This warm weather during the first year of establishment may have reduced the benefits of the warmer soil temperatures under plastic mulch. At Saskatoon and Keeler, growth in terms of height, shoot growth, number of branches and average sucker length were consistently greater than that for plants in bare soil or wood chips but not always significantly different (Tables 1-4). The enhanced growth obtained by using plastic mulch, compared to that for bare soil or wood chips was particularly significant by the end of the second season (2001) at these sites. Only shoot growth of plants mulched with plastic at Keeler was not significantly greater than that for the other mulch treatments in this year. For example, at Saskatoon in 2001, plants grown using plastic mulch were 41% taller with 60% more shoot growth and 47% more branches on average than plants in wood chips or bare soil. At Keeler in 2001, plant height and branch number were 81% and 71% greater, respectively, for plants grown with plastic mulch than for plants grown in wood chips or bare soil. On average, at Keeler and Saskatoon in 2001, plastic mulch increased average sucker length by 1.7 and 2.9 times over that of plants in bare soil and wood chips, respectively.

The wood chip mulch did not enhance plant growth. Growth of plants mulched with wood chips was not significantly different from growth of unmulched plants except for average sucker length which was significantly reduced at Saskatoon (Table 1 and 2). At this site, average sucker length was 6.3 and 1.7 times less for plants grown in wood chips than in bare soil in 2000 and 2001, respectively.

Although wood chip mulch did not improve the growth of saskatoon transplants in this study, organic mulches have been reported to enhance the growth of blueberry (Clark and

Moore, 1991; Patten et al., 1989; Pliszka et al., 1993, 1997; Spiers, 1998), pecan (Foshee et al., 1996; Smith et al., 2000), apple (Måge and Skogerbo, 1992; Merwin et al., 1996; White and Holloway, 1967) and other deciduous fruit trees (Haynes, 1980; Hogue and Neilsen, 1987). Nevertheless, other studies have shown no improvement in plant growth in organic mulch. Schroeder and Faye (1996) found that growth of saskatoons was less vigourous for organic mulches than for plastic mulch or non-mulched checks. In another study, wood chip mulch was found to increase survival but had no effect on plant growth in one (*Salix planifolia*) of four woody species planted in subarctic Quebec (Houle and Babeux, 1994). A newly planted apple orchard showed no consistent trends in cumulative tree growth after four years of using a wood chip mulch (Merwin et al., 1995). Schroeder and Faye (1996) found that at some locations, saskatoon plants in wood chip mulch had a higher population of woolly elm aphids than those in black plastic or controls; woolly elm aphids fed on the roots of the plant and may have contributed to the reduced growth of the plants mulched with wood chips. Reports on the effects of plastic mulch on tree growth also vary. Black plastic mulch was found to increase the growth of young apple trees over those grown in cultivated soil (Måge, 1982; Måge and Skogerbo, 1992). Robinson (1988) concluded that no single mulch type performs best in all situations, but in general apple tree growth was reported to be greater when mulched with black plastic was than straw. However, Måge and Skogerbo (1992) found no differences in apple tree growth between plants grown using bark mulch or black plastic even eight years after planting, but growth using either mulch was greater than that in cultivated soil.

The enhanced growth of saskatoon plants mulched with plastic in this study likely was due to the increase in soil temperature under the plastic mulch. Soil moisture and temperature data were recorded at 15 and 30 cm at Saskatoon in 2000 and 2001, and at Keeler in 2000. Soil under wood chip mulch was cooler than unmulched soil, whereas soil temperatures were increased under black plastic mulch (data not shown). Plastic mulch increased soil temperature on average up to 2 °C at the 15 cm depth, and up to 1 °C at the 30 cm depth. Wood chips reduced soil temperatures by up to 3 °C at the 15 cm depth, and 1 °C at the 30 cm depth. The greatest differences in soil temperature among the three mulch treatments occurred in mid-summer when day-time temperatures were the hottest. Wood chip mulch greatly reduced daily soil temperature fluctuations at the 15 cm depth. At this depth, daily soil temperatures in mid-summer fluctuated by up to 2-3 °C under the plastic mulch, by approximately 2 °C in unmulched plots, and by only 1 °C under wood chips. At the 30 cm depth, daily soil temperature fluctuations were smaller (0.5 °C) and similar under the three treatments. Many previous studies have reported similar results. A reduction in soil temperature was found under organic mulches (Haynes, 1980; Parfitt and Stott, 1884; Schroeder and Faye, 1996; Skroch and Shribbs, 1986; Truax and Gagnon, 1993) and an increase in soil temperature under black plastic mulch (Ashworth and Harrison, 1983; Hogue and Neilsen, 1987; Liakatas et al., 1986; Parfitt and Stott, 1884; Schroeder and Faye, 1996; Skroch and Shribbs, 1986; Truax and Gagnon, 1993). Organic mulches have also been reported to act as a buffer reducing daily soil temperature changes (Ashworth and Harrison, 1983; Hartley and Rahman, 1997; Haynes, 1980; Parfitt and Stott, 1984; Robinson, 1988), whereas daily soil temperature fluctuations under black plastic have been reported to be greater or similar to that in bare soil (Ashworth and Harrison, 1983; Parfitt and Stott, 1984; Robinson, 1988).

Although many previous studies have shown both organic and plastic mulches to conserve soil moisture, and maintain more uniform and higher soil moisture levels between irrigations or rain periods (Faber et al., 2001; Måge, 1982; Merwin et al., 1996; Oliveira and Merwin, 2001; Parfitt and Stott, 1984; Robinson, 1988; Schroeder and Faye, 1996; Skroch and Shribbs, 1986; Truax and Gagnon, 1993) few differences were found in soil moisture levels among the mulch treatments as a result of the regular irrigations received by all treatments. When the soil underwent a substantial drying period between irrigations or periods of rain, soil moisture particularly at the 15 cm depth was lost to a greater extent in the unmulched plots, however, due to the regular irrigations, soil moisture levels under both mulches and the unmulched check were similar most of the time during this study. A greater drying of the soil in unmulched plots was most evident in May before irrigations commenced and in September when the plants were no longer irrigated. Soil moisture under organic mulches was often found to be less variable and greater than under black plastic mulch (Måge, 1982; Robinson, 1988; Schroeder and Faye, 1996; Sun et al., 1994), however, in this study, soil moisture patterns were similar under wood chip and plastic mulch.

Suckering appeared to be hampered by the presence of mulch. Sucker production for plants grown in plastic mulch was 39% and 37% less than that for plants in bare soil in the second season at Outlook and at Saskatoon, respectively, but did not differ at Keeler (Tables 2, 4 and 5). The wood chip mulch had an even greater adverse affect on suckering. Sucker number, and average sucker length of plants in wood chips at Saskatoon in both years were significantly less than that of plants in bare soil or mulched with plastic (Tables 1 and 2). A similar trend was observed at Keeler although this decrease was often not significantly different at this site (Tables 3 and 4). At Saskatoon, the number of suckers produced were 6 and 3 times less for plants in wood chips than for those in bare soil in 2000 and 2001, respectively. In 2000, average sucker length was on average 7.3 times greater for plants grown in bare soil or with plastic mulch than for those in wood chips. In 2001, this difference was less but still significant.

Shcroeder and Faye (1996) found that plastic mulches hampered the suckering of saskatoons, but wood chip mulch encouraged suckering at the soil line just below the mulch layer (Shcroeder and Faye, 1996). However, a thick layer of wood chips (20 cm) was used in this currant study versus the 12.5 cm thick mulch layer used by Schroeder and Faye (1996). The thick layer of mulch may have contributed to the reduced suckering in this study.

Above ground biomass differed significantly among mulch treatments at Keeler but not at the other two sites (Tables 2, 4 and 5). Shoot dry weight was 2.3 times significantly less for plants grown using wood chip mulch than plastic mulch at Keeler. At Saskatoon, shoot dry weight of plants in wood chips was much less than for plants in bare soil or mulched with plastic, however this difference was not quite significant (P=0.0511). The shoot dry weight of plants grown using plastic mulch did not differ from those that were unmulched at all three sites. Plot dry weights, which reflect both growth and survival, did not differ among the mulch treatments at all three sites.

Transplanting month had a great effect on growth and survival. In general, spring transplants had the best overall growth and survival. At Outlook in 2000, May and June transplants had the best survival and greatest growth with the exception of sucker production and average sucker length which were the highest for May and July transplants (Table 5). At this site, May and June transplants were taller in height by an average of 39% than those of the other months. Shoot dry weight was 1.6 to 3.0 times greater for May and June transplants than for those of the other months. Average sucker length was greater for plants transplanted in May and July by an average of 79%, than for transplants of the other months.

The effects of transplant month were more variable at Saskatoon. At this site, May transplants had the greatest survival followed by that in June (Tables 1 and 2). In general, plant height and branch number at Saskatoon were greatest for August and September transplants. Plants transplanted in September were significantly taller the following season than those transplanted in May, June and July by 25% to 71%; differences in height among transplant months were not significant in 2001. In 2001, shoot growth was 86% greater on average for May and July transplants than for June and September transplants. Sucker production and sucker growth at this site were not significantly affected by transplant month. Both shoot dry weight and plot dry weight were highest for May transplants followed by that of September. Plot dry weight was 1.9 to 7.3 times greater for May transplants than for that of the other months.

Plant survival at Keeler ranged from 29% for August transplants to 86% for June transplants in 2000 (Table 3). At this site, May transplants had poor survival and growth likely due to the inadequate irrigation they received following planting in this month. The importance of regular irrigations were conveyed to the growers managing this site following this month. With regards to the remaining transplant months, survival was by far the highest in June. A very large amount of precipitation (296 mm) was received at this site during June and may have been the key factor contributing to the survival of June transplants relative to those of May. Growth at Keeler did not differ among the other transplant months in 2000, but in 2001 shoot growth was 1.9 to 4 times significantly greater for September transplants than for those of the other months, whereas sucker number was greatest for June transplants although not significantly different from those of July and August (Tables 3 and 4). Shoot dry weight was greatest for June transplants followed by that of September transplants, however plot dry weight was significantly highest for June transplants. Plot dry weights in June were 3.2 times greater than the average of that of the other months primarily due to the greater plant survival in this month.

Previous studies have indicated that trees planted in the spring have a better survival and growth than those planted in mid-summer (Hansen, 1986; Emch and Carvell, 1985; Pendl et al., 1990; Roberts and Long, 1991). However, in these studies the effect of planting date was confounded with the period of time the plants were in cold storage, and was based on the planting of dormant plants.

A few significant interactions occurred between mulch treatments and transplant month. Mulch by month interactions occurred for average sucker length at Saskatoon in 2000, shoot growth at Keeler in 2001, and for plant height, and shoot and plot dry weights at Outlook in 2000. At Saskatoon in 2000, September transplants in plastic mulch had 3.7 to10.1 times greater average sucker length than those of the other months; transplant date did not have a significant influence on average sucker length for plants grown in bare soil or wood chips. In 2001 at Keeler, shoot growth of May transplants was greatly enhanced by plastic mulch (15 times greater than unmulched plants), but for July transplants, plastic mulch had a negative effect (5 times less than unmulched plants) on shoot growth. The high soil temperatures under the plastic mulch in July in conjunction with the combined stresses experienced at Keeler may have been responsible for the negative effect on the shoot growth of the July transplants. At Outlook, plants transplanted in June and mulched with black plastic were taller by 32% than unmulched plants, however, July transplants grown with plastic mulch were 22% shorter than the unmulched plants; plant height did not differ significantly between the mulch treatments when planted in the other months. Another interaction at this site indicated that plants transplanted in June and grown using plastic mulch had 58% greater shoot dry weight and 90% greater plot dry weight than that of unmulched plants, whereas no significant differences between the mulched and unmulched treatments existed for transplants of the other months. It is evident that at this site, plastic mulch enhanced the growth of June transplants much more so than transplants of the other months. June transplants would have still been actively growing at the time of planting; transplants at the end of July and subsequent months would have ceased shoot growth and may not have benefitted from the use of plastic mulch the year of planting. However, May transplants should also have demonstrated more growth with plastic than in bare soil, but this was not the case. Growth of July transplants mulched with plastic may have been adversely affected by the warmer soil temperatures during this month.

Conclusions

Transplant month had a great effect on the survival and establishment of non-dormant saskatoon transplants. In general, spring planting (late May until late June) resulted in the best survival and growth followed by that in September. Late June planting is not always advisable as the temperatures at this time of the year can often be similar to that of mid-summer. Therefore, transplanting into the field in late May to mid-June would be recommended.

More research needs to be done to adequately discern the effects of both plastic and wood chip mulch on survival and growth of saskatoon transplants. It appears that plastic mulch can be beneficial in enhancing plant growth, however, if plants are stressed, survival can be adversely affected. The use of plastic mulch combined with the spring planting of healthy plants may result in significantly greater growth without a decrease in plant survival. Although plants in wood chip mulch often exhibited a significantly greater survival than that in plastic, they did not exhibit an increase in growth. In addition, wood chip mulch appeared to be detrimental to sucker production and sucker growth. This may be a great concern particularly for cultivars that are not as profuse in suckering as Smoky. A thinner layer of the wood chip mulch may not have had the same negative effect on suckering. Plants in this study were actively growing when transplanted to the field. The planting of dormant plants may have yielded different results for both the effect of planting month and mulching.

Other factors that determine the advantages of mulching that have not been addressed in this study include the cost of the mulch material, its application, and maintenance. The economic savings in weed control, environmental impact and public concerns with the use of herbicides, and potential increases in returns through greater yields should also be considered. The use of mulches can be of great benefit where weed control is a problem. Although this study did not take into account the effect of the mulches on weed control, Schroeder and Faye (1996) estimated that the time devoted to weeding was reduced by 95% and 75% for saskatoon plants grown in plastic and organic mulches, respectively. Future research examining the long-term effects of soil mulches on saskatoon growth, flowering and fruiting would also be valuable.

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Table 1. The survival and growth in 2000 of saskatoons transplanted in 1999 at Saskatoon, SK, as affected by mulch type and transplant month.

	Survival (%)	Height (cm)	Shoot Growth (cm)	Number of Branches	Sucker Number	Average Sucker Length (cm)
Mulch						
None	60.8 ab[1]	27.5	8	2.4	0.6 b	1.9 b
Plastic	48.3 a	31.4	9.3	2.6	0.5 b	2.5 b
Wood Chips	68.3 b	25.6	8.3	2.1	0.1 a	0.3 a
S.E.[2]	4.5	1.96	1.05	0.31	(0.060)[3]	-0.154
Month						
May	91.7 d	25.6 a	8.2	2.2 ab	0.2	1.1
June	70.8 c	27.8 ab	6.1	2.1 ab	0.4	1.3
July	22.2 a	20.4 a	11.2	1.3 a	0.5	1.6
August	48.6 b	32.3 bc	8.8	3.1 b	0.3	0.9
September	62.5 bc	34.8 c	8.3	3.0 b	0.6	2.7
S.E.	5.82	2.51	1.35	0.4	-0.077	-0.198
Mean	59.2	28.2	8.5	2.3	-0.95	-1.4

[1] For mulch and month treatments separately, means within a column followed by the same letter are not significantly different using LSD ($P \leq 0.05$).

[2] Standard error of the mean.

[3] Transformed means and standard errors are presented within brackets if data were transformed prior to analysis.

Table 2. The survival and growth in 2001 of saskatoons transplanted in 1999 at Saskatoon, SK, as affected by mulch type and transplant month.

	Survival (%)	Height (cm)	Shoot Growth (cm)	Number of Branches	Sucker Number	Average Sucker Length (cm)	Shoot Dry Weight (g)	Plot Dry Weight (g)
Mulch								
None	60.8 b[1]	36.8 a	10.1 a	5.3 a	3.8 c	10.6 b	45.3	134.2
Plastic	47.5 a	49.2 b	16.2 b	7.5 b	2.4 b	19.4 c	42.8	95.1
Wood Chips	68.3 b	33.0 a	10.2 a	4.9 a	1.2 a	6.4 a	26.8	78
S.E.[2]	4.51	3.07	1.41	(0.116)[3]	-0.11	1.53	-0.497	-0.946
Month								
May	90.3 d	40.7	16.4 c	4.5 a	2.4	14.3	62.9 c	227.3 c
June	70.8 c	34.1	7.8 a	5.8 ab	2.5	10.1	32.3 ab	97.9 b
July	22.2 a	35	16.3 bc	4.1 a	1.9	12.6	17.7 a	31.1 a
August	48.6 b	46	10.6 ab	7.9 b	2.3	10.5	37.6 ab	75.6 ab
September	62.5 bc	42.6	9.8 a	7.2 b	3	13.1	46.0 bc	121.6 b
S.E.	5.82	3.93	1.81	-0.149	-0.141	1.96	-0.638	-1.214
Mean	58.9	39.7	12.2	-2.52	-1.7	12.1	-6.19	-10.08

[1] For mulch and month treatments separately, means within a column followed by the same letter are not significantly different using LSD ($P \leq 0.05$).

[2] Standard error of the mean.

[3] Transformed means and standard errors are presented within brackets if data were transformed prior to analysis.

Table 3. The survival and growth in 2000 of saskatoons transplanted in 1999 at Keeler, SK, as affected by mulch type and transplant month.

	Survival (%)	Height (cm)	Shoot Growth (cm)	Number of Branches	Sucker Number	Average Sucker Length (cm)
Mulch						
None	54.2 ab[1]	15.4 a	8.1	1.2 a	0.7	1.8
Plastic	42.5 a	28.2 b	10.7	2.5 b	0.6	2.1
Wood Chips	61.7 b	14.7 a	6.8	1.6 a	0.3	1.6
S.E.[2]	5.21	1.62	1.15	0.22	0.14	(0.20)[3]
Month						
May	58.3 b	12.2 a	5.9	1.2	0.2	0.7
June	86.1 c	21.0 b	9.6	1.9	0.7	2.9
July	44.4 ab	22.2 b	8.8	2	0.5	2.1
August	29.2 a	20.1 b	8.5	1.7	0.5	1.6
September	45.8 ab	21.4 b	9.9	2.1	0.7	2.3
S.E.	6.73	2.08	1.48	0.29	0.18	-0.26
Mean	52.8	19.4	8.5	1.8	0.5	-1.5

[1] For mulch and month treatments separately, means within a column followed by the same letter are not significantly different using LSD ($P \leq 0.05$).

[2] Standard error of the mean.

[3] Transformed means and standard errors are presented within brackets if data were transformed prior to analysis.

Table 4. The survival and growth in 2001 of saskatoons transplanted in 1999 at Keeler, SK, as affected by mulch type and transplant month.

	Survival (%)	Height (cm)	Shoot Growth (cm)	Number of Branches	Sucker Number	Average Sucker Length (cm)	Shoot Dry Weight (g)	Plot Dry Weight (g)
Mulch								
None	50.8	18.1 a[1]	4.7	1.0 a	1.4	8.1 a	14.1 ab	28.2
Plastic	40	30.9 b	7.8	1.8 b	1.2	13.0 b	21.4 b	38.3
Wood Chips	57.5	16.0 a	4.4	1.1 a	0.8	4.6 a	9.2 a	21.3
S.E.[2]	5.1	1.9	(0.22)[3]	0.22	0.19	1.61	2.78	-0.634
Month								
May	47.2 b	15.6 a	2.9 a	1	0.5 a	4.6	8.4 a	13.4 a
June	83.3 c	23.9 b	6.2 b	1.7	1.7 c	10.3	24.5 c	70.3 b
July	44.4 ab	20.7 ab	4.6 ab	1.1	1.5 bc	9.4	12.3 ab	25.0 a
August	26.4 a	20.8 ab	3.8 ab	1.2	1.0 abc	11.4	11.1 ab	15.9 a
September	45.8 b	27.3 b	11.7 c	1.5	0.9 ab	7.1	18.1 bc	33.5 a
S.E.	6.59	2.44	-0.28	0.28	0.25	2.06	3.57	-0.815
Mean	49.4	21.7	-2.45	1.3	1.1	8.5	14.9	-5.42

[1] For mulch and month treatments separately, means within a column followed by the same letter are not significantly different using LSD ($P \leq 0.05$).

[2] Standard error of the mean.

[3] Transformed means and standard errors are presented within brackets if data were transformed prior to analysis.

Table 5. The survival and growth in 2000 of saskatoons transplanted in 1998 at Outlook, SK, as affected by plastic mulch and transplant month.

	Survival (%)	Height (cm)	Shoot Growth (cm)	Number of Branches	Sucker Number	Average Sucker Length (cm)	Shoot Dry Weight (g)	Plot Dry Weight (g)
Mulch								
None	68.7	65.1	29.1	8.6 a[1]	3.8 b	31.8	104.4	314
Plastic	62	68.6	30.1	9.9 b	2.3 a	30.2	99.3	350
S.E.[2]	5.03	1.96	2.44	0.44	0.29	2.81	(0.349)[3]	34.1
Month								
May	83.3 b	82.5 b	37.3 c	11.5 b	3.8 bc	42.0 b	166.8 c	586 b
June	90.0 b	78.2 b	33.8 bc	13.3 b	2.7 ab	26.1 a	145.9 c	551 b
July	48.3 a	59.1 a	21.4 a	8.4 a	4.1 c	42.3 b	97.4 b	233 a
August	50.0 a	59.7 a	31.5 abc	6.5 a	2.2 a	19.3 a	70.2 ab	138 a
September	55.0 a	54.7 a	23.8 ab	6.5 a	2.5 ab	25.3 a	52.0 a	153 a
S.E.	7.96	3.1	3.86	0.7	0.45	4.44	-0.551	53.9
Mean	65.3	66.9	29.6	9.2	3.1	31	-10.12	332

[1] For mulch and month treatments separately, means within a column followed by the same letter are not significantly different using LSD ($P \leq 0.05$).

[2] Standard error of the mean.

[3] Transformed means and standard errors are presented within brackets if data were transformed prior to analysis.

The Impact of Heading-back Dormant Saskatoon Plants During Orchard Establishment

****This study is incomplete due to the termination of the Native Fruit Development Program. Two to four more years of data would be required to adequately assess the results of the experimental treatments applied in terms of yield in particular.***

Background

For several years, certain fruit production experts have been vigorously promoting a radical pruning technique for newly-transplanted saskatoons which is not based on any published or publicly-available, scientifically-based methodology, data or analyses, and which contradicts currently-accepted horticultural studies on pruning woody transplants. It's well-established in the literature that woody plants do not benefit from radical pruning at the time of transplanting (Abod and Webster 1990; Chandler 1990; Day and Johnson 1999; Harris *et al.* 1999; Hartman *et al.* 2000; Smiley and Booth 2000; Struve 1990; Watson and Himelick 1997). In general, pruning dwarfs plants and can have a negative effect on economic yields early in the establishment of an orchard because woody plants require a certain amount of growth before they flower and produce fruit. If there is merit in this pruning technique, then the promotion of this technique must first be based on well-founded science. To do otherwise could have a very negative impact on the industry. Consequently, this trial was established to determine the impact of heading-back on the survival, growth and yield of three saskatoon cultivars.

Methods

Micropropagated clones of three cultivars (Northline, Smoky and Thiessen) were obtained from Prairie Plant Systems (Saskatoon, SK) and were placed in a shade-house for approximately two weeks to acclimate the plants to outdoor conditions. The trial was planted at the Plant Sciences research plots, University of Saskatchewan, on May 28, 1999.

Heading-back treatments included: no heading-back, heading-back dormant plants to 2.5 cm from the soil surface during year 2, and heading-back dormant plants to 2.5 cm from the soil surface during year 4. The first heading-back treatment was applied on April 19, 2000, prior to bud-break. The second heading-back treatment was applied in April of 2002. All treatment combinations were arranged in the field using a randomized complete block design with 3 replicates of 5 plants per replicate.

Data collection to date has included plant survival, number of suckers, number of branches, shoot growth from main stem, plant height, and sucker length, measured at the end of the growing season. Once fruit production occurs, yield and fruit size data will be collected.

Field Seasons 2000 & 2001

The results of the ANOVA for the year 2000 indicated significant differences among cultivars for growth and number of suckers/plant, and significant differences among the heading-back treatments for all variables except sucker length. The interaction between cultivar and heading-back was significant for plant height. The associated data are found in Tables 1, 2, and 3. Heading-back plants during year 2 appeared to have a negative impact on transplant survival (Table 1) but these plants later recovered and were present when the 2001 survival data were collected (Table 5). Shoot growth, plant height, branch number and sucker number were all negatively affected by heading-back. Average sucker length did not differ significantly between treatments. However, the cumulative sucker length was reduced in headed-back group as a consequence of reduced sucker number.

Table 1. Effect of heading-back on survival, plant height, branching, shoot growth and suckering, 2000.

Treatment	Survival %	Height (cm)	Branch number	Shoot Growth (cm)	Sucker number	Cumulative Sucker Length (cm)	Average Sucker Length
Control	92.6 a	24.1 a	2.16 a	13.7 a	3.0 a	13.2 a	4.3 a
Year 2 Headed-back	81.5 b	9.8 b	0.61 b	8.0 b	1.9 b	6.4 b	3.1 a
Year 4 (treatment not applied)	91.9 a	23.5 a	2.08 a	13.1 a	3.1 a	12.4 a	3.9 a

Different letters within a column indicate significant treatment differences ($P \leq 0.05$).

Differences in shoot growth were observed between cultivars (Table 2) where the cultivar Northline produced less shoot growth, but more suckers/plant than the other cultivars in the trial.

Table 2. Effect of cultivar on shoot growth & number of suckers/plant, 2000.

Cultivar	Shoot Growth (cm)	Number of suckers/plant
Northline	8.6 a	2.89 a
Smoky	14.0 b	1.47 b
Thiessen	12.1 b	1.62 b

Different letters within a column indicate significant treatment differences ($P \leq 0.05$).

Plant height was measured at the end of the 2000 season. The headed-back plants of each cultivar were not as high as the untreated plants of that cultivar (Table 3). This effect appeared to be most pronounced in the cultivar Northline.

Table 3. Combined effect of cultivar and heading-back on plant height, 2000.

Cultivar	Treatment	Height
Northline	Control	24.3 a
	Year 2 Headed-back	4.8 b
	Year 4 (treatment not applied)	21.6 a
Smoky	Control	26.7 a
	Year 2 Headed-back	14.6 c
	Year 4 (treatment not applied)	22.1 a
Thiessen	Control	21.3 a
	Year 2 Headed-back	10.1 bc
	Year 4 (treatment not applied)	26.8 a

Different letters within a column indicate significant treatment differences ($P \leq 0.05$).

The results of the ANOVA for the year 2001 indicated significant differences among cultivars for plant height, number of branches growth, and number of suckers, and among heading-back treatments for height, number of branches, growth, number of suckers, and total length of suckers. The associated data are found in Tables 4 and 5. Shoot growth, sucker number and plant height were significantly different for all three cultivars (Table 4). Shoot growth and plant height were greatest for the cultivar Smoky and least for the cultivar Northline. The cultivar Northline produced the greatest number of suckers while the cultivar Thiessen produced the fewest suckers. Branch number and average sucker length were lower in the cultivar Northline than the cultivars Smoky and Thiessen. Survival and cumulative sucker length did not differ between cultivars.

Table 4. Effect of cultivar on survival, plant height, branching, shoot growth and suckering, 2001.

Cultivar	Survival %	Height (cm)	Branch Number	Shoot Growth (cm)	Sucker Number	Cumulative Sucker Length (cm)	Average Sucker Length
Northline	88.1 a	23.9 a	3.2 a	7.7 a	9.7 a	67.2 a	5.4 a
Smoky	91.9 a	35.7 b	4.6 b	17.6 b	6.8 b	81.6 a	10.5 b
Thiessen	94.0 a	30.3 c	4.5 b	13.0 c	4.7 c	59.3 a	10.1 b

Different letters within a column indicate significant treatment differences ($P \leq 0.05$).

It became apparent during the 2001 season that heading-back did not reduce plant survival as indicated from the data collected during the 2000 season. Treatments that appeared to be dead during the previous season grew back and all treatments showed equal survival rates. However, plant height, branching, shoot growth, sucker number, and cumulative sucker length were substantially negatively affected by the heading-back treatment applied at the beginning of the previous season. Average sucker length was not affected by heading-back (Table 5).

Table 5. Effect of heading-back on survival, plant height, branching, shoot growth and suckering, 2001.

Treatment	Survival %	Height (cm)	Branch number	Growth (cm)	Sucker number	Cumulative Sucker Length (cm)	Average Sucker Length
Control	91.1 a	35.8 a	5.2 a	13.7 a	7.6 a	79.1 a	9.7 a
Year 2	91.1 a	17.3 b	2.0 b	9.6 b	5.1 b	47.3 b	7.5 a
Year 4	91.9 a	36.7 a	5.1 a	15.0 a	8.4 a	82.0 a	8.8 a

Different letters within a column indicate significant treatment differences ($P \leq 0.05$).

Field Season 2002

The results of the ANOVA for the year 2002 indicated significant differences among cultivars for plant height, branch number, shoot growth, sucker length, and number of suckers, and among heading-back treatments for height, number of branches, growth, number of suckers, and sucker length. The associated data are found in Tables 6 and 7.

Plant height was similar among the cultivars Thiessen and Smoky. Plants of the cultivar Northline were on average approximately half as tall as the cultivars Thiessen and Smoky. Shoot growth and sucker number was significantly different for all three cultivars (Table 6). Shoot growth was greatest for the cultivar Smoky and least for the cultivar Northline. Sucker number was greatest for the cultivar Northline and least for the cultivar Thiessen. The cultivar Smoky produced greater cumulative sucker length than the other cultivars. The average sucker length of the cultivar Northline was approximately half that of the other two cultivars.

Table 6. Effect of cultivar on survival, plant height, branching, shoot growth and suckering, 2002.

Cultivar	Survival %	Height (cm)	Branch Number	Shoot Growth (cm)	Sucker Number	Cumulative Sucker Length (cm)	Average Sucker Length
Northline	87.4 a	23.6 a	3.6 a	11.0 a	17.4 a	230 a	11.1 a
Smoky	91.1 a	48.1 b	7.9 b	26.8 b	13.4 b	343 b	24.4 b
Thiessen	92.9 a	43.2 b	6.8 b	22.1 c	8.5 c	243 a	25.4 b
Different letters within a column indicate significant treatment differences ($P \leq 0.05$).							

The second heading back treatment was applied at the beginning of the 2002 season prior to bud break. Plant height, branching, shoot growth, sucker number, cumulative sucker length, and average sucker length were affected by either or both of the heading-back treatments (Table 7). Branching was reduced by both heading-back treatments. However, this was particularly evident in the most recently headed-back treatments where the average branch number was reduced to 1.3. Shoot growth was greatest in plants that were headed-back at the beginning of the fourth season. This wasn't surprising considering overall plant growth was concentrated on fewer branches. However, plants that were headed-back during the spring of 2002 were only half the height of plants that were not headed-back at all. Average sucker length was reduced in both headed-back treatments. Sucker number was less in the headed-back treatments applied during the second year than the control group and the most recently headed-back plants. Sucker production was unaffected by heading-back during year 4. The cumulative sucker length was less in plants belonging to the year 2 headed-back treatment relative to those headed-back during year 4 and the control group. It appears that larger, more established plants are better able to recover after the top portion of the plant was removed. However, there is no evidence to date indicating that heading-back plant at year 2 or year 4 has any beneficial impact on plant growth or shape.

Table 7. Effect of heading-back on survival, plant height, branching, shoot growth and suckering, 2002.

Treatment	Survival %	Height (cm)	Branch number	Growth (cm)	Sucker number	Cumulative Sucker Length (cm)	Average Sucker Length
Control	91.1 a	52.1 a	10.3 a	17.8 a	13.7 a	310 a	22.9 a
Year 2 Headed-back	88.9 a	36.7 b	6.7 b	17.1 a	9.4 b	184 b	18.2 b
Year 4 Headed-back	91.1 a	26.0 c	1.3 c	25.1 b	16.0 a	323 a	20.0 b
Different letters within a column indicate significant treatment differences ($P \leq 0.05$).							

The cultivar by treatment interaction was significant for height, growth, branching and cumulative sucker length (Table 8). Plant height was reduced by both heading-back treatments in the cultivars Northline and Thiessen and of these, the plants headed-back during the fourth year were smaller than plants headed-back during the second year. Plant heights among the headed-back treatments of the cultivar Smoky followed the same pattern but these differences weren't statistically significant. Plants of the cultivar Smoky responded to being headed-back during the fourth season with greater growth of the primary shoot relative to all other cultivar by heading-back treatment combinations. The was no difference in shoot growth between the headed-back treatments within the other cultivar groups. Heading-back plants after 4 years resulted in reduced branching in all cultivars. The cultivars Northline and Thiessen also had reduced branching when heading-back occurred during year 2. However, plants of the cultivar Smoky that were headed-back during year 2 produced just a many branches as the control group. The effect of the heading-back treatments on cumulative sucker length varied among all three cultivars tested

Table 8. Combined effect of cultivar and heading-back on plant height, 2002.

Cultivar	Treatment	Height (cm)	Growth (cm)	Branch number	Cumulative Sucker Length (cm)
Northline	Control	39.1 c	13.4 a	6.9 c	314 c
	Year 2 Headed-back	21.9 b	10.7 a	3.7 b	170 ab
	Year 4 Headed-back	9.7 a	9.0 a	0.3 a	207 b
Smoky	Control	53.2 d	17.0 ab	12.5 d	300 bc
	Year 2 Headed-back	47.2 cd	20.6 b	10.2 d	239 b
	Year 4 Headed-back	43.9 cd	42.9 c	1.0 ab	490 d
Thiessen	Control	64.1 e	23.1 b	11.5 d	318 c
	Year 2 Headed-back	41.0 c	19.9 b	6.5 bc	142 a
	Year 4 Headed-back	24.3 b	23.4 b	2.4 a	271 bc

Different letters within a column indicate significant treatment differences ($P \leq 0.05$).

Field Season 2003

The results of the ANOVA for the 2003 season indicated significant differences among cultivars for all parameters measured in this study except survival. Significant differences were found in the heading-back treatments for height, growth and branch number. The associated data are found in Tables 9 and 10. There were no significant cultivar by heading-back treatment interactions.

Plant height was similar among the cultivars Thiessen and Smoky. Plants of the cultivar Northline were, on average, approximately half as tall as the cultivars Thiessen and Smoky. Shoot growth and sucker number was significantly different for all three cultivars. Shoot growth and branching was greatest for the cultivar Smoky and least for the cultivar Northline. Sucker production was greatest for the cultivar Northline and least for the cultivar Thiessen. The cultivar Smoky produced greater cumulative sucker length while the cultivar Northline had the least. The average sucker length of the cultivar Northline was approximately half that of the cultivar Smoky. The average sucker length of the cultivar Thiessen fell between the other two cultivars.

Fewer plants of the cultivar Northline were flowering than the other two cultivars tested. Meaningful yield data was not collected during the 2003 season since yields were very low and highly variable due to substantial fruit losses and damage as a result of bird feeding in this trial.

The second heading-back treatment was applied at the beginning of the 2002 season prior to bud break. At the end of that season, height and branching was reduced by this treatment. Surprisingly, height and branching was found to increase in this treatment during the 2003 season. All parameters relating to sucker production and sucker growth were unaffected by any of the heading-back treatments. Since the thinning treatments were not applied there is a considerable amount of hidden replication of the two remaining factors in this trial. This allows for subtle treatment differences to be determined. For example, an increase of approximately 2 branches per plant, occurring as a consequence of heading-back plants during season 4, was found to be statistically significant. At this stage in the trial it is impossible to determine what the long-term impact of this slight increase in branching would be. Similarly plant height was greatest in the second heading-back treatment during the 2003 season. Plant growth was increased by the second heading back treatment during the 2002 season but the reverse was found during the 2003 season. This suggests that seasons of increased growth in response to heading-back may be followed by reduced growth during the next growing season.

Table 9. Effect of cultivar on survival, flowering, plant height, branching, shoot growth and suckering, 2003.

Cultivar	Survival %	Plants Flowering %	Height (cm)	Branch Number	Shoot Growth (cm)	Sucker Number	Cumulative Sucker Length (cm)	Average Sucker Length
Northline	86.7 a	11.1a	40.2 a	5.9 a	15.5 a	4.7 a	26.8 a	4.9 a
Smoky	91.1 a	69.6 b	79.5 b	12.8 b	28.5 b	3.5 b	46.1 b	11.0 b

Thiessen	91.1 a	66.7 b	70.2 b	10.3 c	22.1 c	1.3 c	15.0c	6.8 c

Different letters within a column indicate significant treatment differences ($P \leq 0.05$).

Table 10. Effect of heading-back on survival, flowering, plant height, branching, shoot growth and suckering, 2003.

Treatment	Survival %	Flowering %	Height (cm)	Branch number	Growth (cm)	Sucker number	Cumulative Sucker Length (cm)	Average Sucker Length
Control	91.9 a	49.6 a	61.5 a	9.0 a	25.1 a	2.9 a	29.4 a	8.3 a
Year 2 Headed-back	86.7 a	42.9 a	55.8 a	8.7 a	20.5 b	3.0 a	26.5 a	6.7 a
Year 4 Headed-back	90.4 a	54.8 a	72.5 b	11.3 b	19.6 b	3.5 a	32.5 a	7.9 a

Different letters within a column indicate significant treatment differences ($P \leq 0.05$).

Conclusions

There was no indication at the end of the 2001 field season that the heading-back of dormant plants improves plant establishment or increases plant height, branching, shoot growth or number of suckers for any cultivar. Two years after the first heading-back treatment was applied, a substantial reduction in plant size and branch number of the headed-back plants was observed.

Differences between cultivars had a greater impact on the parameters measured during this study than either of the heading-back treatments that were applied. Transplant survival was unaffected any of the cultivar or heading-back treatments. The cultivar Northline had fewer plants that flowered than the other cultivars tested regardless of when the heading-back treatment was applied. There were no significant cultivar by heading-back treatment interactions found during the 2003 season.

The first heading-back treatment initially appeared to negatively impact some growth parameters but these effects were largely overcome by the end of the 2003 growing season. It seems that heading-back effects diminish as growing seasons pass since there was almost no differences found between plants that were headed-back during season two and those that were not headed-back at all. The second heading-back treatment resulted in reduced growth, an increase in plant height, and a slight increase in branching during the 2003 season. There is no evidence to date that these small treatment effects would have an impact on yield.

Heading-back saskatoon transplants has been promoted to improve plant shape, reduce sucker production, reduce years to flowering and to increase yield. The purpose of this study was in part designed to evaluate the merits of this practice. Based on the results observed to date and considering the time and labour involved in conducting this practice, there is no reason to encourage growers to head-back their plants either in year 2 or year 4 of orchard establishment.

It is important to note that this study is incomplete due to the termination of the Native Fruit Development Program. Two to four more years of data would be required to adequately assess the results of the experimental treatments applied in terms of yield in particular.

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Effects of Propagation Method and Cultivar on Transplant Survival and Growth

***This study is incomplete due to the termination of the Native Fruit Development Program. Another two to fours years of data would be required to adequately assess the results of the experimental treatments applied in terms of yield in particular.**

Objectives

The objective of this trial was established to determine the impact propagation method on transplant establishment, plant growth and yield of several saskatoon cultivars.

Methods

Seedling and micropropagated plant material of the cultivars Smoky, Thiessen, Northline were used in this study. The seedling plant material was obtained from Select Seedling Nursery (Saskatoon, SK) and the micropropagated plant material was obtained from Prairie Plant Systems (Saskatoon, SK). Treatments consisting of 5 plants were transplanted in a field trial at the University of Saskatchewan (Saskatoon, SK) on May 31, 1999. This trial was arranged in a randomized complete block design (RCBD) with 4 replicates. One meter spacing was placed between plants, 2 meter spacing was used to separate treatments and a 4.5 meter spacing used between the rows. Each row of this trial contained one replicate.

Poor quality micropropagated plant material and grazing damage from rabbits precluded the collection of meaningful data for the 2000 to 2002 field seasons. Survival, plant height, growth of the main stem, branch number, number of suckers, total sucker length, and average sucker length data were collected during the 2003 growing season. Yield data could be not be collected because this trial suffered substantial fruit losses and damage as a result of bird feeding.

Results and Discussion

The results of the ANOVA of the 2003 data indicated that some growth parameters were significantly affected by cultivar and propagation method (Tables 1 and 2). There were also some significant effects of cultivar by propagation method interaction (Table 3). Throughout the trial period, none of the treatments or treatment interactions had any impact on plant survival.

During the 2003 season, shoot growth was similar among all the cultivars tested. However, plants of the cultivar Northline were shorter than plants of cultivars Smoky and Thiessen. Branching, average sucker growth and total sucker growth was greater in the cultivar Smoky than the other two cultivars tested. Sucker production was less in the cultivar Thiessen than the cultivars Smoky and Northline (Table 1).

A comparison of the seedling and clonal plants, combining all the cultivar data, showed differences in number of branches, sucker production, average sucker growth and total sucker growth. All of these growth parameters were greater in the seedling group (Table 2).

The results of the analysis of variance for the 2003 season indicated significant cultivar by treatment interactions in plant height, shoot growth and total sucker length. Clonally propagated plants of the cultivar Northline were shorter than all other treatment combinations. Clonally propagated plants of the cultivar Smoky had significantly greater shoot growth than all other treatment combinations. Plants of the cultivar Smoky that were propagated from seed had much greater total sucker growth than all other propagation method by cultivar combinations (Table 3).

Table 1. The effect of cultivar on survival, plant height, branching, shoot growth and suckering, 2003.

Cultivar	Survival %	Height (cm)	Branch Number	Shoot Growth (cm)	Sucker Number	Cumulative Sucker Length (cm)	Average Sucker Length (cm)
Northline	95 a	56.8 a	8.5 a	14.7 a	5.7 a	35.2 a	5.2 a
Smoky	100 a	75.8 b	11.8 b	18.3 a	7.6 a	99.2 b	12.7 b
Thiessen	100 a	70.4 b	9.8 a	16.7 a	2.0 b	19.1 a	7.6 a

Different letters within a column indicate significant treatment difference (P ≤0.05).

Table 2. The effect of propagation method on survival, plant height, branching, shoot growth and suckering, 2003.

Treatment	Survival %	Height (cm)	Branch Number	Shoot Growth (cm)	Sucker Number	Cumulative Sucker Length (cm)	Average Sucker Length (cm)
Clone	96.7 a	63.5 a	8.7 a	17.9 a	3.4 a	25.9 a	6.9 a
Seedling	100 a	71.8 a	11.2 b	15.2 a	6.8 b	76.4 b	7.6 a

Different letters within a column indicate significant treatment difference (P ≤0.05).

Table 3. The effect of cultivar and propagation method on survival, plant height, branching, shoot growth and suckering, 2003.

Treatment	Cultivar	Surviva l %	Height (cm)	Shoot Growth (cm)	Branch Number	Sucker Number	Cumulative Sucker Length (cm)	Average Sucker Length (cm)
Clone	Northline	90	40.2 a	13.2 a	6.2	4.7	20.9 a	4.3
Clone	Smoky	100	85.3 c	24.2 b	11.7	3.9	40.8 a	9.8
Clone	Thiessen	100	65.1 b	16.2 a	8.3	1.7	15.9 a	6.7
Seedling	Northline	100	73.4 bc	16. 2 a	10.9	6.7	49.5 a	6
Seedling	Smoky	100	66.5 b	12.4 a	12	11.3	157.5 b	15.6
Seedling	Thiessen	100	75.7 bc	17.1 a	10.7	2.4	22.4 a	8.5
Different letters within a column indicate significant treatment difference ($P \leq 0.05$).								

Conclusions

Data collection in this trial was seriously compromised by poor quality micropropagated plant material and animal pest problems. These effects likely were mitigated to some extent by the fourth field season. Nevertheless, this field trial would require several more seasons in order to adequately measure the effects of propagation method on growth and yield.

The data generally indicated that poor quality plant material, as obtained from the propagator, has a significant negative effect on plant growth. The data also generally indicated that the effects of cultivar were greater than the effects of propagation method.

It appears that growers who have planted seedling-propagated plants can expect a greater number of suckers and increased sucker growth. It is unclear at this point whether this would have any impact on yield, either positively or negatively, in the long-term. It is probable however that this difference in plant growth habit would increase the amount of labour needed to keep this growth in check.

The cultivars can generally be characterized in the following manner: The cultivar Thiessen produces fewer suckers than the cultivars Smoky and Northline. The cultivar Smoky produces much more sucker growth and a slightly greater number of branches than the other two cultivars tested. The cultivars Smoky and Thiessen are similar in height.

It is important to note that this study is incomplete due to the termination of the Native Fruit Development Program. Two to four more years of data would be required to adequately assess the results of the experimental treatments applied in terms of yield in particular.

3.2.4. Information Development And Distribution To The Fruit Industry

Objectives

The objective of this activity was to develop, or revise, and distribute information to the fruit industry, and to provide problem-solving and diagnostic services for the industry.

Deliverables

Deliverables for this activity were to include the following: 1) The 10 currently available manuals will continue to be distributed; 2) Updated factsheets for the saskatoon manual may be completed, where possible, if resources permit; 3) The HTML code and files for the Native Fruit Development Website will be made available to SAFRR for use on their website; and 4) Problem-solving and diagnostic services will be provided to the industry on request, provided that resources are available.

Results

Since the last Native Fruit Program Annual Report (December 2002), the Program has received 492 requests for information, and 46 saskatoon manuals, and 31 other manuals have been distributed. Problem-solving and diagnostic services were provided to the industry on request. Adequate resources were not available to create updated factsheets for the saskatoon manual, primarily because personnel were either let go, or left to take positions elsewhere due to the termination of the Native Fruit Program and a substantial budget decrease in comparison to previous years. The HTML code and files for the Native Fruit Development Program website are included on the CD containing the electronic version of this report.

3.2.5. Identification Of Research Gaps

Information has been distributed that indicates that the Native Fruit Development Program has succeeded in completing all of the research that needs to be done in terms of saskatoon production. However, in contrast to this information, the reality of the situation is that it is obvious that a considerable amount of research remains to be done in the following production related areas:

a) Determinants of yield. Most growers still are averaging only about 3500 kg of fruit per hectare. This represents a significant difference from experimental trial data, but the reasons for this are various and unclear. Greater average yields are critical to the economic success of the industry.

b) Integrated pest management. A significant amount of work needs to be done in this area including more pesticide screening and registration, development of monitoring methods for insect pests and diseases, determination of the effects of cultural practices (irrigation, fertilization, pruning, etc.) on insect pest and disease populations, and variety development (including selection, propagation & testing) as insect and disease resistant genotypes in particular are part of the foundation of a successful integrated pest management system. The saskatoon as a crop likely will run into critical long-term insect pest and disease problems without ongoing work in this area.

c) Fruit quality as it relates to environment, cultural practices, harvest and postharvest storage practices. How can the crop management system be optimized so that the fruit produced are of a consistent high quality? Fruit quality begins to deteriorate immediately once the fruit are harvested and therefore the quality of any processed product is dependent on the production system and how well this is integrated with the weather.

3.2.6. Inventory Of Experimental Sites And Materials

The experimental designs for the studies conducted are described in the Materials and Methods of all applicable reports.

Field plans/layouts follow. Field plans for the transplant study were not included as the study involved destructive harvests and therefore no longer exists. Approximately 150 pages of handwritten and typed germplasm inventories are contained in files left in the Department of Plant Sciences at the University of Saskatchewan.

Saskatoon Accession Plot - Block

1 m between plants
2 m betweeen rows

Planted June 12, 1990
as seedlings

Steeves - 56

Steeves - 56

Steeves - 56

Beaver Lodge - 56

Beaver Lodge - 56

N

Montana - 56

Montana - 43 Cypress Hills - 8

Cypress Hills - 55

Stephenfield Prov. Park - 56

Stephenfield Prov. Park - 56

East Shoal Lake - 56

East Shoal Lake - 56

East Shoal Lake - 56

Whiteshell-McGillivary Tr. - 56

Whiteshell-McGillivary Tr. - 56

Whiteshell-McGillivary Tr. - 56

Good Spirit Lake - 56

Good Spirit Lake - 56

Good Spirit Lake - 56

Lake Minnewasta - 56

Lake Minnewasta - 48 - Sandilands - 8

Great Falls - 28 7503 Row5 'Regent' - 26

Row 7-7505 'Success' - 56

60-0055 'Pear' - 33, A. x Grandiflora - 1, A. bartramiana - 3, 60-0061 A. ovalis - 13, 60-0062 A. ovalis - 3, A. ovalis - 2

A. spicata - 56

A. gaspensis - 56

A. gaspensis - 56

A. gaspensis - 56

311-16 #11 - 56

Thiessen-5, St74430 - 2, St74-129 - 1, SB89-11 - 11, SB89-12 - 13, SB89-13 - 3, SB89-16 - 1, SB89-17 - 4, SB89-19a - 2, SB89-20a - 6, SB89-1 - 1

New Saskatoon Accessions U. of S.

N

Reid #1 (60)

35 Engele (60)

Gallaher NW (60)

Eberts (60)

Gallaher RF (60)

Reid #2 (60)

30 Holodniuk (60)

Campbell (8) **SP (1)** Bargholz (9) **SP (1)** AlWes Shell Lake (41)

Dyck (43) **SP(1)** AlWes (12) **SP (1)** Meadow Lake (3)

Innes/Borden (60)

Reid #3 (29) **SP(1)** Innes/Borden (30)

25 Reid #3 (60)

Wicks (60)

Soron (37) **SP(1)** Wicks (22)

Muir (6) **SP(1)** Soron (53)

Muir (60)

20 Innes/Alvina (60)

Thiessen (10) SP(1) Martin (3) SP(1) Forestburg (14) SP(1) Regent (5) SP(1) Bluff (3) SP(1) Pembina (5) SP(1) Innes/Alvina (14

Honeywood (16) **SP(1)** Pearson II (11) **SP(1)** Buffalo (14) **SP(1)** A.spicata (11) **SP(1)** A.a.1177 (4)

Smox Req (5) **SP(1)** Par 90 (17) **SP(1)** Northline (27) **SP(1)** Quaker (8)

A.s.102 (7) **SP(1)** A. fernaldi (12) **SP(1)** A.a.98 (14) **SP(1)** A.s.c. 51 (24)

15 A.s.102 (60)

A.interior (26) **SP(1)** A. intermedia (33)

A.a.5 (4) **SP(1)** Success (55)

Success (24) **SP(1)** Parkhill (35)

Parkhill (50) **SP(1)** Hawes '98 (9)

10 Hawes '98 (60)

Hawes '98 (60)

Kalenchuk (60)

Kalenchuk (60)

Hawton (60)

5 Beaubier (60)

Senga (60)

Senga (60)

Hawes '97 (60)

1 Hawes '97 (60)

Note: 60 plants/row **SP** = spacer plant (highbush cranberry)

Rows 28-36 planted 2002 Rows 1-8 & 17-27 planted 2001 Rows 9-16 planted 2000

◄ N

Saskatoon Cultivar Trial
U. OF S.

↕ Direction of Rows

Planted Aug. 1991
5 plants/cultivar/rep

Rep 1				Rep 2				Rep 3			
Par 90 TRS	Martin	Forestburg	---	Quaker	Pearson II	Regent	Martin	Success	Thiessen	Honeywood	Northline
Regent	Honeywood	Success	Bluff	Honeywood	Buffalo	Smoky	Success	Nelson	Buffalo	Pasture	Bluff
Buffalo	Pearson II	Pembina	Smoky	Northline	Parkhill	---	Pasture	Parkhill	Forestburg	Par 90 TRS	Pembina
Thiessen	---	Nelson	Parkhill	---	Bluff	---	Nelson	---	Martin	Quaker	Smoky
Pasture	Northline	Quaker	---	Forestburg	Par 90 TRS	Pembina	Thiessen	Pearson II	---	---	Regent

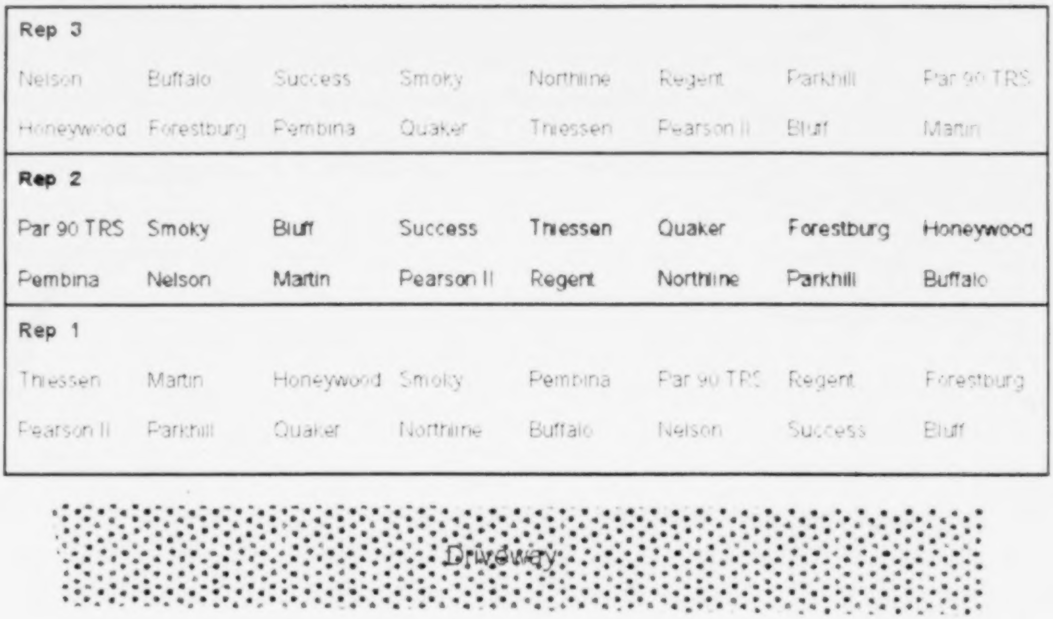
ROAD

N

Saskatoon Cultivar Trial
PORTER'S

Direction of Rows

Planted 1991
5 plants/cultivar/rep



Rep 3

Nelson	Buffalo	Success	Smoky	Northline	Regent	Parkhill	Par 90 TRS
Honeywood	Forestburg	Pembina	Quaker	Thiessen	Pearson II	Bluff	Martin

Rep 2

Par 90 TRS	Smoky	Bluff	Success	Thiessen	Quaker	Forestburg	Honeywood
Pembina	Nelson	Martin	Pearson II	Regent	Northline	Parkhill	Buffalo

Rep 1

Thiessen	Martin	Honeywood	Smoky	Pembina	Par 90 TRS	Regent	Forestburg
Pearson II	Parkhill	Quaker	Northline	Buffalo	Nelson	Success	Bluff

N →

Black Currant Cultivar Trial
U. of S. SITE 1

↕ Direction of Rows

Rep 3	Wellington	Crusader	Boskoop Giant	Black Giant	5-24-9	Consort
	Willoughby	Coronet	25-23-23	Magnus	Topsy	5-23-42
Rep 2	Coronet	5-24-9	25-23-23	Boskoop Giant	Crusader	Wellington
	Consort	Magnus	5-23-42	Topsy	Black Giant	Willoughby
Rep 1	Magnus	Topsy	25-23-23	Crusader	Consort	5-23-42
	Wellington	5-24-9	Coronet	Black Giant	Boskoop Giant	Willoughby

Planted August 1994
5 plants/cultivar/rep

← N

Black Currant Cultivar Trial
U. of S. SITE 2
Block 14

↕ Direction of Rows

Ben Lomond	Ben Sarek	Consort	Magnus	Noir de B.	4-24-29
Ben Alder	4-24-29	Crusader	Noir de B.	Ben Sarek	Crusader
Consort	Ben Nevis	McGinnis Black	Ben Alder	Ben Lomond	Titania
Noir de B.	Magnus	Titania	4-24-29	McGinnis Black	Wellington
McGinnis Black	Titania	Ben Lomond	Wellington	Ben Alder	Magnus
Wellington	Crusader	Ben Sarek	Ben Nevis	Ben Nevis	Consort
Rep 1		Rep 2		Rep 3	

Planted May 1998
5 plants/cultivar/rep

N ⟶

Chokecherry Cultivar Trial
U of S SITE

↕ Direction of Rows

Rep 3	? Espenant	Garrington	Copper Shubert	Mini Shubert	Lee
	Maxi	Robert	Mission Red	Yellow	Goertz
Rep 2	Mini Shubert	Garrington	Goertz	Lee	Copper Shubert
	Yellow	Mission Red	Robert	Maxi	? Espenant
Rep 1	Goertz	Yellow	Maxi	Mission Red	? Espenant
	Robert	Copper Shubert	Garrington	Lee	Mini Shubert

Planted August 1994
5 plants/cultivar/rep

N →

Pincherry Cultivar Trial
U. of S. SITE

↕ Direction of Rows

Rep 3	Jumping Pound	---
	Mary Liss	Lee #4
Rep 2	---	Lee #4
	Mary Liss	Jumping Pound
Rep 1	Lee #4	Mary Liss
	---	Jumping Pound

Planted August 1994
5 plants/cultivar/rep

N →

Highbush Cranberry Cultivar Trial
U. of S. SITE

↕ Direction of Rows

Rep 3	Manito	Phillips	---	Garry Pink
	Espenant	Wentworth	Andrews	Alaska
Rep 2	Garry Pink	Wentworth	Andrews	Espenant
	---	Manito	Phillips	Alaska
Rep 1	Wentworth	---	Phillips	Manito
	Espenant	Garry Pink	Alaska	Andrews

Planted August 1994
5 plants/cultivar/rep

Variety Evaluation Trial
SIDC - OUTLOOK

N →

	Raspberry	Chokecherry	Highbush Cranberry	Black Currant	Pincherry	Sour Cherry
	SK84-34	Lee	Alaska	Willoughby	Mary Liss	6-69-11.0
Rep 3	SK84-35	Garrington	Phillips	Wellington	Jumping Pound	6-68-25.1
	Boyne	Yellow	Wentworth	Consort	Lee #4	6-69-2.6
	Boyne	**Yellow**	**Phillips**	**Wellington**	**Mary Liss**	**6-69-2.6**
Rep 2	**SK84-35**	**Garrington**	**Alaska**	**Consort**	**Jumping Pound**	**6-68-25.1**
	SK84-34	**Lee**	**Wentworth**	**Willoughby**	**Lee #4**	**6-69-11.0**
	SK84-34	Lee	Alaska	Wellington	Jumping Pound	6-69-2.6
Rep 1	Boyne	Yellow	Wentworth	Consort	Lee #4	6-69-11.0
	SK84-35	Garrington	Phillips	Willoughby	Mary Liss	6-68-25.1

Note: 1 m between plants, 2 m between varieties, 3 m between reps, 5 m between rows
5 plants/variety
Planted Fall 1994

← N

Pruning Experiment
U. of S.

↕ Direction of Rows

G 2C	B 3B	P 2B
B 2A	G 3A	G 3C
G 1A	P 3A	P 2A
G 3B	G 1B	B 1B
B 3A	B 2C	B 3C
P 2C	B 1A	P 3B
P 1A	G 2A	G 2B
B 1C	B 2B	P 3C
G 1C	P 1B	P 1C

Rep 1

B 1B	B 1C	G 2B
P 3A	B 3C	B 3B
G 1B	G 3C	P 2B
B 1A	P 3C	P 1B
G 2A	G 1A	P 2A
P 1C	G 2C	B 2B
B 3A	B 2C	G 3A
B 2A	P 2C	G 3B
G 1C	P 1A	P 3B

Rep 2

P 3C	B 1C	G 2A
P 1A	B 2A	P 1C
B 1A	B 3A	G 1A
P 2A	G 2C	B 3C
P 3B	B 1B	G 2B
G 1B	G 3B	G 3C
G 1C	P 2C	B 2B
P 2B	G 3A	P 3A
B 2C	P 1B	B 3B

Rep 3

Note: 0.75 m between plants
1.5 m between treatments
5 plants/treatment

G - green - Thiessen
B - blue - Smoky
P - pink - Northline

A - No thinning
B - Remove 25% of branches years 4 and 6
C - Remove 50% of branches years 4 and 6

1 - Head back to 1 inch above ground (April 23, 2002)
2 - Head back to 1 inch above ground (April 19, 2000)
3 - No heading back

← N

Tissue Culture vs. Seedling Experiment
U. of S. SITE

↕ Direction of Rows

Rep 1	Rep 2	Rep 3	Rep 4
O - Northline	O - Northline	O - Thiessen	P - Smoky
P - Northline	O - Thiessen	P - Northline	P - Northline
P - Thiessen	P - Smoky	P - Thiessen	O - Thiessen
P - Smoky	P - Northline	P - Smoky	O - Northline
O - Smoky	O - Smoky	O - Northline	P - Thiessen
[illegible] - Thiessen	P - Thiessen	O - Smoky	[illegible]

Note: 1 m between plants
2 m between treatments
5 plants/treatment

O = Seedling
P = Tissue

Planted May 31, 1999

3.3. ADF Project Reports

Progress or Final Reports for the ADF projects 19990317 (A model to forecast Entomosporium), 20000232 (IPM strategy for control of Entomosporium leaf and berry spot), and 20020069 (Screening of insecticides) have been submitted under separate cover.

3.4. Manuscripts Submitted To Refereed Journals

Four scientific manuscripts of the results of recently-completed projects/activities have been written. These manuscripts include: a) Comparative Agronomic Performance of 15 Saskatoon (*Amelanchier alnifolia* Nutt.) Cultivars At Maturity; b) Fruit Quality Assessment of 16 Saskatoon (*Amelanchier alnifolia* Nutt.) Cultivars; c) Comparative Agronomic Performance of Cultivars of Choke Cherry (*Prunus virginiana* L.), Pin Cherry (*Prunus pensylvanica*), and Highbush Cranberry (*Viburnum trilobum* Marsh.), Grown in Saskatchewan; and d) Fruit Physicochemical Properties of Cultivars of Choke Cherry (*Prunus virginiana* L.), Highbush Cranberry (*Viburnum trilobum* Marsh.), and European Black Currant (*Ribes nigrum* L.) Grown in Saskatchewan.

These manuscripts are in the process of being submitted to various scientific journals.

Comparative Agronomic Performance of 15 Saskatoon (*Amelanchier alnifolia* Nutt.) Cultivars At Maturity

R.G. St-Pierre, A.M. Zatylny, and H.P. Tulloch

Abstract

The cultivar performance of mature plants of 15 saskatoon cultivars grown in replicated cultivar trials at two sites (University of Saskatchewan and Moonlake, SK) were quantitatively characterized and compared over 5 years (1999-2003). The 15 cultivars included Bluff, Buffalo, Forestburg, Honeywood, JB30, Martin, Nelson, Northline, PAR 90, Parkhill, Pearson II, Pembina, Smoky, Success, and Thiessen. Data were collected on total yield, marketable yield, fruit size, evenness of ripening, ripening date and shoot growth. Of the cultivars tested, JB30, Thiessen and Martin produced both high yields (3.25-3.97 kg/plant total yield; 2.88-3.62 kg/plant marketable yield) and large fruit (13.3-13.9 mm diameter). The cultivars Pearson II, Honeywood, Smoky, Northline and Forestburg produced high yields (4.09-4.70 kg/plant total yield; 3.72-4.16 kg/plant marketable yield) and medium-sized fruit (12.1-12.4 mm in diameter). Fruit of the cultivars PAR 90, JB30, Thiessen, Success, Martin and Honeywood matured 4-7 days earlier than that of Northline, Parkhill, Buffalo and Nelson. Fruit of Pembina ripened significantly later than that of all of the other cultivars by 6-13 days. No consistent differences existed among the cultivars in their evenness of ripening. Shoot extension growth differed among the cultivars ranging from an average of 10.5 cm/yr for Parkhill to 21.4 cm/yr for JB30. Shoot growth steadily decreased each year from 1999 to 2003 approaching a plateau as the plants reached maturity.

Funding for this project was provided by Saskatchewan Agriculture and Food.

Introduction

The saskatoon (*Amelanchier alnifolia* Nutt.) is a fruit-bearing shrub native to the North American prairies. In the U.S., it is commonly known as a juneberry or serviceberry. Its berry-like pome fruit, once widely used by indigenous people and early settlers on the prairies, are still popular today among the local population eaten fresh, or processed into jams, syrups and pie fillings (Harris, 1970). Interest in the commercial production of the saskatoon has increased substantially in recent years, with approximately 1200 ha currently planted on the Canadian prairies.

There are approximately 26 named cultivars of saskatoons, all of which have been selected from the wild or as a seedling of a named cultivar (St-Pierre, 1997). In the past, saskatoon cultivar descriptions and recommendations were based on non-replicated trials, qualitative and anecdotal information. The first extensive replicated cultivar trials of saskatoons were established by the University of Saskatchewan, Saskatoon, SK. Comparative agronomic data for saskatoon cultivars during the phase of orchard establishment are available (Zatylny et al., 2002), but comparable data for mature plants is not available. The objective of the current study was to characterize the agronomic performance of mature plants of 15 fruit-bearing cultivars of saskatoon.

Materials and Methods

The cultivar trials initially were difficult to establish because of problems with propagation and consequent lack of availability of plant material. The trial was originally established at seven sites; six of these were grower-managed sites located throughout Saskatchewan. Five of these sites were eventually excluded from the study because of site-related issues including excessive browsing by deer, lack of irrigation, excessive salinity, and poor management on the part of the co-operator. Data from the remaining two sites are presented in this paper.

Fifteen saskatoon cultivars were planted in replicated trials at the University of Saskatchewan (U of S) in Saskatoon, Saskatchewan (52°N), and at a grower-managed site approximately 15 km southwest of the city of Saskatoon (Moonlake). The trial consisted of a randomized complete block design with three blocks at each of the two sites. Each plot within a block contained five plants. The 15 cultivars tested included Bluff, Buffalo, Forestburg, Honeywood, JB30, Martin, Nelson, Northline, PAR 90, Parkhill, Pearson II, Pembina, Smoky, Success, and Thiessen. Of these, the cultivars Parkhill and Success originated in the United States, and are likely hybrids of *A. stolonifera* with *A. alnifolia* (Weir, 1995); all other cultivars are *A. alnifolia*.

One year old saskatoon plants were planted in the fall of 1991. The cultivars JB30, Pembina and Smoky were propagated from cuttings; all other cultivars were micropropagated. Plant spacing was set at 1 m within a row and 4.5 m between rows. Because of difficulties in propagation, not all cultivars were available in 1991. PAR 90 and JB30 (at both sites) and Forestburg (Moonlake) were planted in 1992; Nelson was planted at both sites in 1993. Replacement planting of plants that did not survive occurred in the spring and fall of 1992 and 1993, and in the spring of 1994.

The sites were maintained using recommended management practices (St-Pierre, 1997a). These included the use of registered pesticides to control insects, disease, and weeds. Manual weeding and cultivation were also used. Both sites were irrigated when necessary during the first four years of establishment. The U of S site was set up permanently under drip-irrigation and continued to be irrigated when necessary. The removal of diseased and damaged wood and low lying branches was conducted each year as required. Regular rejuvenation pruning of the plants involving the removal of old wood at ground level and/or thinning out of the canopy commenced in the spring of 2000 and was carried out each year as required. In general, the U of S site was managed more intensively than the Moonlake site.

Yield: Fruit were mechanically harvested in two harvests from two plants in each plot. The first harvest occurred when at least 60% of the fruit on the plants were ripe. The second harvest was done when the majority of the remaining fruit were ripe. All fruit from each sampled plant were mechanically harvested with hand-held shakers (BEI, South Haven, MI) which were raked along the branches causing the fruit to fall into catch frames below. Mechanical harvesting removed some under-ripe fruit. Immature fruit as well as any diseased, damaged or shrivelled fruit were sorted out by hand to obtain marketable yields.

Fruit Size: The number of fruit in one cup, and fruit diameter were used to measure fruit size. The number of ripe fruit required to fill a one cup measure (250 mls) was counted and recorded. Fruit diameter was measured from 30 randomly selected fruit per plot.

Evenness of Ripening: From The percentage of ripe fruit on the plants within a plot were visually assessed for ripeness based on fruit colour during the 1998, 1999 and 2000 growing seasons. The number of days that it took for the plants to go from 10% to 90% ripe fruit was calculated.

Ripening Date: The Julian date that 50% of the fruit on the plants within a plot were visually estimated to be fully ripe was recorded during the 1998, 1999 and 2000 growing seasons.

Shoot Growth: The current season's shoot growth was measured from 15 randomly selected shoots per plot from the mid-portion of the plants. Measurements were recorded in August after shoot growth had ceased.

Data Analysis: The data were checked for normality and transformed when necessary using a square root transformation prior to statistical analysis. Back-transformed means, the transformed standard error, and the transformed overall mean are presented in the tables for data that were transformed prior to analysis. The data were analyzed using the Mixed procedure of SAS (SAS Institute Inc., Cary, NC). Sites and years were considered as random factors with blocks nested within both. Cultivar separation was accomplished by the LSMEANS (least-square means; equivalent to an LSD) option of SAS at a probability level ≤ 0.05. The GLM procedure of SAS was used to obtain the means of the random factors, and to analyze the interaction of year with site for data on fruit size.

Results and Discussion

Yield: Cultivars differed significantly in both their total and marketable yields (Table 1). The highest yielding cultivars included Bluff, Martin, Buffalo, Thiessen, JB30, Forestburg, Northline, Smoky, Honeywood, and Pearson II. Total yields and marketable yields for these cultivars ranged from 3.04 and 2.76 kg/plant for Bluff to 4.70 and 4.10 kg/plant for Pearson II, respectively. The total yields of Success and Pembina (mean = 1.34 kg/plant) were significantly lower than that of all other cultivars but Nelson. Pearson II, Honeywood, and Smoky had significantly greater marketable yields (mean = 4.14 kg/plant) than that of PAR 90, Parkhill, Nelson, Success, and Pembina (mean = 1.76 kg/plant). Pembina had a much lower percentage of marketable fruit than all the other cultivars except Success. Fruit of Pembina tended to shrivel on the plant soon after ripening, which would account for its greater percentage of unmarketable fruit.

Cultivar rankings of plant productivity from 1999-2004 were similar to the rankings of cumulative yield over the first five years of production (Zatylny et al., 2002) with the exception of Parkhill and JB30. Parkhill, a precocious producer, initially outyielded a number of the cultivars but, when mature ranked amongst the less productive cultivars. Yields of JB30 from its first five years of production were low relative to most of the other cultivars, whereas mature plants of JB30 ranked amongst the higher yielding cultivars. JB30 appears to have taken longer to get into full production, but this cultivar was also planted one year later than most of the other cultivars. Figure 1 shows that the yields of JB30 were greater in 2000 than in 1999, whereas most cultivars produced less in 2000 than in 1999.

The yield performance of Smoky, Honeywood, Forestburg and Northline in these trials agrees with previous observations of these cultivars (McConkey, 1979; St-Pierre, 1997b), however, that of Pembina does not. Pembina has been reported to be very productive (McConkey, 1979; St-Pierre, 1997b), but this study has indicated the opposite. Pembina is an older cultivar, having been introduced in 1956 (Zatylny and St-Pierre, 2003). It may be possible that the plants in this study are not the true Pembina clones, but perhaps a seedling of Pembina that unknowingly was propagated as Pembina.

The poor yields of Success and Nelson may be attributed to their small plant size. At the U of S site in particular, the plants of these cultivars were considerably shorter than at Moonlake. Yields of these cultivars at Moonlake were 137% and 56% greater for Success and Nelson, respectively, than at the U of S (data not shown). The heavier clay soil at the U of S site may have not been suitable for growing these cultivars. The soil at Moonlake is a lighter texture (clay loam) which is more favourable for growing saskatoons. However, the yields of Nelson at the two sites did not differ significantly. Nelson also was planted two years after the other cultivars, nevertheless its yield in 2003 was less than in 1999 suggesting that it had reached its mature yield by 1999.

Typical patterns of yearly yield fluctuations from 1999-2003 are shown in Figure 1. For most cultivars, high yielding or 'on' years appear to be followed by low yielding or 'off' years, indicating a tendency towards alternate bearing. Some evidence for alternate bearing in saskatoons was also demonstrated in data on flowering collected from 2001-2003 (data not shown); the total number of flowers on the previous season's shoot growth was found to alternate from high to low to high again, matching the pattern found for total yield. The higher yielding cultivars such as Smoky, Pearson II, Honeywood and Forestburg tended to have the greatest yearly fluctuations in yield. Other cultivars such as Bluff, Buffalo, Martin, Northline, PAR 90, Permbina and JB30 experienced years of alternating high and low yields that were less extreme, similar to that of Thiessen shown in Figure 1. This alternating pattern of yearly yields did not commence until 2000 for the cultivars Bluff, Martin and JB30, indicating that the mature yields of these cultivars may not have been reached in 1999. Yearly yields of the remaining cultivars, Nelson, Parkhill and Success, did not follow this alternating pattern; the yields of these cultivars declined in 2003 from that of the previous year instead of increasing. This decline may have been the result of the annual renewal pruning that commenced three years earlier; this pruning may have set back these shorter cultivars moreso than the taller ones.

Fruit Size: Fruit size was determined by measurements of fruit diameter and the number of fruit/cup (Table 1). The cultivars fell into four different distinct categories of fruit diameters. Cultivars with the largest fruit diameters included Thiessen, Martin, PAR 90 and JB30 (mean = 13.7 mm). The fruit of Thiessen and Martin were significantly larger in diameter than JB30 by 4%. The fruit of Smoky, Nelson, Honeywood, Northline, Pearson II, and Forestburg fell into the second largest category with a mean diameter of 12.2 mm. Buffalo, Pembina and Parkhill were in the third category with a mean fruit diameter of 11.4 mm. Success and Bluff had the smallest fruit (mean diameter = 10.9 mm).

Cultivar rankings of fruit size as measured by fruit/cup were similar to that of fruit diameter but with fewer distinct differences amongst the medium-sized fruit. The fruit of Martin, Thiessen, PAR 90 and JB30 were on average almost twice the size of that of Success and Bluff. Cultivar rankings of fruit size were similar overall to that found in previous years of this trial (Zatylny et al., 2002).

It is worthwhile to note that fruit size was smaller in the years 2001 and 2002 (Figure 2). These two years were very dry years with below average precipitation. Fruit size was reduced to a greater extent at Moonlake. The U of S orchard was irrigated regularly, however, the Moonlake site did not have a permanent irrigation set up and was not irrigated on a regular basis. Statisical analysis accomplished by Proc GLM to examine the interaction of year and site for these parameters indicated that fruit size measured as fruit/cup and diameter was significantly smaller at Moonlake in 2001 and 2002 than at the U of S site, and that of all other years at both sites. These results emphasize the importance of adequate irrigation in ensure optimum fruit size is achieved particularly during years of drought.

Evenness of Ripening: Evenness of ripening of fruit on a plant is a desirable trait when mechanical harvesters are used in order to enable a once-over harvest. However, no consistent differences existed among the cultivars in evenness of ripening as recorded as the number of days required for the plants to go from 10% to 90% ripe fruit (Table 1). Variability was large from year to year and between the sites. On average, it took approximately two weeks from the onset of ripening to completion.

Ripening Date: The cultivars differed in their harvest dates as measured as the Julian day that 50% of the fruit on a plant were fully ripe (Table 1). Fruit of the cultivars PAR 90, JB30, Thiessen, Success, Martin and Honeywood matured 4-7 days earlier than that of Northline, Parkhill, Buffalo and Nelson. Fruit of Pembina ripened significantly later than that of all of the other cultivars by 6-13 days.

Shoot Growth: Shoot growth differed significantly among the cultivars (Table 1). Annual shoot growth was significantly greater for the cultivars JB30, PAR 90 and Thiessen (mean = 19.4 cm) than that of Honeywood, Pembina, Smoky, Pearson II and Parkhill (mean = 13.0 cm). The remaining cultivars were intermediate in their shoot growth ranging from 14.8 cm to 17.6 cm. The relative amount of shoot growth amongst the cultivars changed dramatically from previous years for some of the cultivars but not for others. In 1994, Pearson II and Smoky had a large amount of shoot growth similar to that of Thiessen and Martin (Zatylny et al., 2002), but from 1999-2003 had significantly less shoot growth than these cultivars. In general, the shoot growth of the cultivars has decreased over the last five years as the plants approach their mature size (Figure 3).

Conclusions

This study enabled the quantitative characterization and direct comparison of 15 mature saskatoon cultivars from replicated trials at two sites over five years. Previously, data from replicated trials was not available for mature plants of these cultivars. Such information is directly valuable to the grower. High yielding cultivars with good fruit size are important for the commercial production of saskatoons. An orchard of cultivars with different harvest times are beneficial in extending the harvest period. Of the cultivars tested, those with high yields and a large fruit size included JB30, Thiessen and Martin. Pearson II, Honeywood, Smoky, Northline and Forestburg had high yields and medium-sized fruit. Pearson II, Honeywood and Smoky tended to have the highest fruit yields among these cultivars although not significantly different, but also had a greater tendency towards alternate bearing. Of these cultivars, JB30, Thiessen, Martin and Honeywood fruited earlier than Northline.

Many other factors need to be considered when choosing a cultivar for production; these include disease and insect resistance, suckering, blossoming time, post-harvest storage and fresh fruit quality. Data on some of these characteristics have been previously published (Zatylny et al., 2002; Ronald, 2001), however more cultivar screening needs to be done in the area of insect and disease resistance. Future research should also examine differences in the fresh fruit storageability of the cultivars.

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Table 1. Agronomic characteristics of 15 saskatoon cultivars from 1999 to 2003 grown at two sites in Saskatchewan, the U of S and Moonlake.

Cultivar	Total Yield (kg/plant)	Marketable Yield (kg/plant)	Fruit Diameter (mm)	Number of Fruit/Cup	Days from 10 to 90% Ripe Fruit[1]	Julian Days to 50% Ripe Fruit[1]	Shoot Growth (cm)
Bluff	3.04 bcde[2]	2.76 cde	10.9 a	236 e	11.5	200.5 bcde	16.9 cde
Buffalo	3.86 cde	3.18 cde	11.4 b	186 cd	14.8	201.7 de	14.8 bcde
Forestburg	4.09 cde	3.72 de	12.4 c	165 b	14.3	197.8 abc	15.6 bcde
Honeywood	4.67 e	4.16 e	12.1 c	173 bcd	13.8	197.4 ab	14.2 bcd
JB30	3.97 cde	3.62 de	13.3 d	126 a	14	197.0 ab	21.4 f
Martin	3.25 bcde	2.88 cde	13.8 e	111 a	14.4	197.4	17.6 def
Nelson	2.14 ab	1.88 bc	12.1 c	167 bc	15.4	203.4 e	15.2 bcde
Northline	4.14 cde	3.74 de	12.2 c	168 bcd	13.3	201.1 cde	15.0 bcde
PAR 90	2.78 bcd	2.49 cd	13.7 de	112 a	13.2	196.2 a	18.5 ef
Parkhill	2.73 bc	2.46 cd	11.5 b	188 d	15.4	201.3 cde	10.5 a
Pearson II	4.70 e	4.16 e	12.2 c	169 bcd	13.9	198.4 abcd	13.0 ab
Pembina	1.36 a	0.72 a	11.4 b	182 bcd	11.8	209.3 f	14.2 bcd
Smoky	4.58 de	4.10 e	12.1 c	172 bcd	15	198.1 abcd	13.3 abc
Success	1.32 a	1.23 ab	10.8 a	214 e	11.8	197.1 ab	N/A[3]
Thiessen	3.94 cde	3.56 de	13.9 e	111 a	14	197.0 ab	18.5 ef
Mean	(1.81)[4]	(1.69)	12.3	(12.78)	13.8	199.6	(3.94)
S.E.[5]	(0.216)	(0.201)	0.197	(0.435)	1.87	1.50	(0.574)

[1] Data from 1999 and 2000 only.

[2] Means within a column followed by the same letter are not significantly different ($P \leq 0.05$).

[3] Data not available.

[4] The transformed mean and transformed standard error are presented in brackets when the data were transformed prior to analysis.

[5] Standard error of the mean.

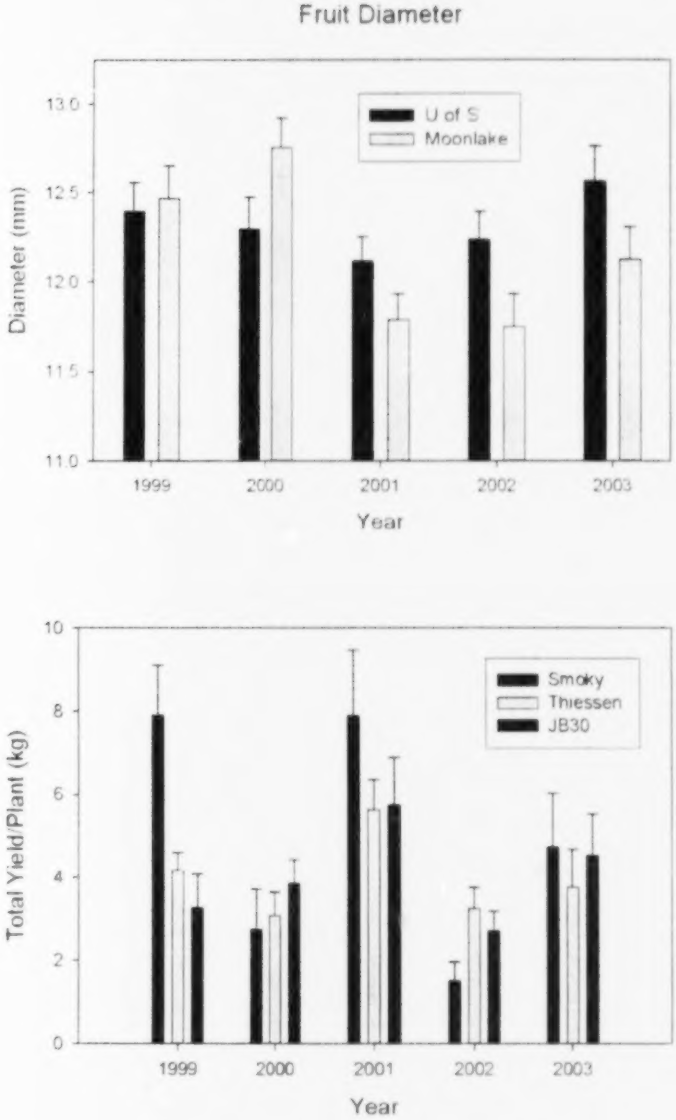

Figure 1. Three representative patterns of yearly fluctuations in yield of the saskatoon cultivars grown at the U of S and at Moonlake from 1999 to 2003.

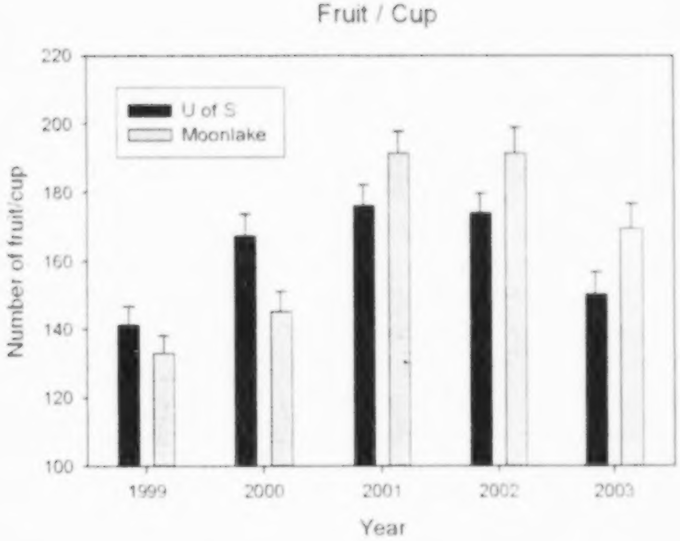

Figure 2. Mean fruit diameter and fruit/cup of 15 saskatoon cultivars at the U of S and Moonlake from 1999 to 2003.

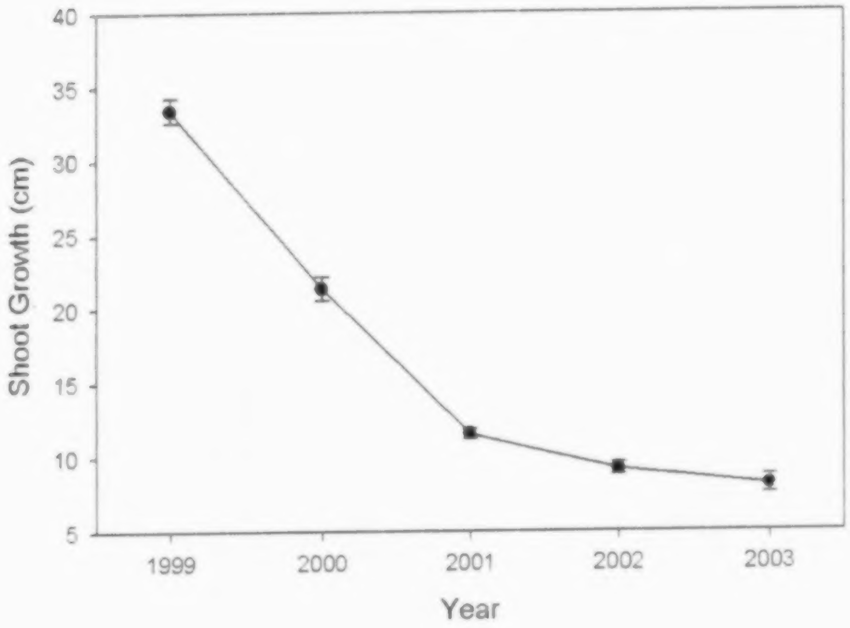

Figure 3. Average shoot growth per year of 15 saskatoon cultivars grown at the U of S and Moonlake from 1999 to 2003.

Physicochemical Properties of Fruit of 16 Saskatoon (*Amelanchier alnifolia* Nutt.) Cultivars

A.M. Zatylny, W.D. Ziehl and R.G. St-Pierre

Abstract

Physicochemical properties were assessed for the fruit of 16 saskatoon (*Amelanchier alnifolia* Nutt.) cultivars harvested from 1998 to 2000 from replicated cultivar trials at two sites (Saskatoon and Moonlake, SK). The cultivars included Bluff, Buffalo, Elizabeth (at Saskatoon only), Forestburg, Honeywood, JB30, Martin, Nelson, Northline, PAR 90, Parkhill, Pearson II, Pembina, Smoky, Success, and Thiessen. Fruit weight, total solids, soluble solids, pH, titratable acidity, anthocyanin content, and colour characteristics of the fruit juice extracts were measured. Fruit of Martin, Thiessen and PAR 90 had the highest 10 fruit weights of the cultivars (mean = 16.3 g) and Success and Bluff the lowest (mean = 7.9 g). Total solids and soluble solids contents ranged from 19.9% and 14.0 °Brix, respectively for fruit of JB30 to 27.9% and 20.1 °Brix, respectively for fruit of Pembina. Fruit pH ranged from 3.65 for Nelson to 4.18 for Parkhill and Smoky. Fruit of Nelson had a titratable acidity level (0.63%) approximately twice that of Success, Pearson II, Forestburg, Honeywood, Smoky and Parkhill. The soluble solids to titratable acidity (SS/TA) ratio differed greatly among the cultivars ranging from 27 for JB30 to 55 for Parkhill. The colour characteristics of the fruit juice extracts differed among the cultivars in their chroma and L values but not in their hue angle. Anthocyanin analysis by HPLC identified four peaks, cyanidin-3-galactoside, cyanidin-3-glucoside and two unknowns. Total fruit anthocyanin content ranged from 414 µg/g for Forestburg to 852 µg/g for Nelson. Significant correlations were found between anthocyanin content and fruit pH, titratable acidity, hue angle and L value.

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Introduction

The saskatoon (*Amelanchier alnifolia* Nutt.), a shrub of the Rosaceae family, is a fruit native to the North American great plains. In the United States it is commonly called the juneberry or serviceberry. Its dark purple, berry-like pome fruit range in diameter from 10 to 15 mm on average depending on the cultivar (Zatylny et al., 2002). The fruit, collected from wild stands, were traditionally used by aboriginal people and early settlers on the prairies. At present, the commercial production and marketing of saskatoons has become more widespread. The fruit are eaten fresh or commonly processed into jams, jellies, syrups, pie fillings and wine.

There are approximately 26 named cultivars of saskatoon (St-Pierre, 1997), 16 of which are currently being tested in replicated trials at the University of Saskatchewan, Saskatoon, SK. Some fruit quality characteristics of only seven of these 16 cultivars have been previously published from fruit harvested from unreplicated orchards (Green and Mazza, 1986; Green and Mazza, 1988; Mazza, 1986; Rogiers and Knowles, 1997, 1998, 2000; Davidson and Mazza, 1991). This study presents the analysis and comparison of the physicochemical properties of the fruit of these 16 saskatoon cultivars from replicated cultivar trials over three years and at two locations. This permits an accurate comparison of cultivar characteristics as physicochemical fruit properties can vary with growing location and harvest year due to climactic and soil differences, thereby limiting the validity of comparisons made among different studies. This information will provide a basis for the future evaluation of fruit of new selections, as well as a knowledge base for the developing saskatoon fruit processing industry.

Materials and Methods

The fruit were harvested from replicated trials of 16 saskatoon cultivars at the University of Saskatchewan (U of S) in Saskatoon, Saskatchewan, and from 15 cultivars at a grower-managed site approximately 15 km southwest of Saskatoon (Moonlake). The trials were established as randomized complete block designs with three blocks at each site. Five plants of each cultivar were planted in a plot randomized within each block. The cultivars included Bluff, Buffalo, Elizabeth (at U of S only), Forestburg, Honeywood, JB30, Martin, Nelson, Northline, PAR 90, Parkhill, Pearson II, Pembina, Smoky, Success, and Thiessen. All cultivars are *A. alnifolia* except for Parkhill and Success which likely are hybrids of *A. stolonifera* with *A. alnifolia* (Weir, 1995). Due to difficulties in propagation, the cultivars PAR 90 and JB30 (at both sites) and Forestburg at Moonlake were planted in 1992 and Nelson was planted in 1993; all other cultivars were planted in 1991.

Fruit analyses were conducted on saskatoon fruit harvested from 1998 to 2000 from both locations. Depending on the type of analysis, laboratory tests were conducted on two or three sub-samples of fruit harvested from each replicated plot in the field.

All fruit were mechanically harvested with hand-held shakers (BEI, South Haven, MI) which were raked along the branches causing the fruit to fall into catch frames below. Harvested fruit were placed in plastic containers (25 x 19 x 8 cm) (Item Code PCA 9745, PCA Canada, Scarborough, ON) and put into an insulated wooden container between layers of ice substitute (Cyropak Corp., Vancouver, BC). Fruit were stored in this field cooler for up to seven hours before being frozen at -40 °C in the plastic containers.

Ten fruit weight, total solids and soluble solids contents, and pH were determined for fruit harvested from both sites and over the years 1998-2000. Fruit titratable acidity was assessed for fruit harvested from the U of S site in 1999 and 2000. Ten fruit weight was determined by weighing 10 frozen fruit. Total solids content was measured according to AOAC method 920.151 (AOAC, 1995) in which 15 g of fruit were dried in a vacuum oven at 70°C for 24 hours. Juice was extracted from the fruit for measurements of pH and soluble solids content by manually macerating 50 g of fruit and decanting the liquid portion. The pH was measured and soluble solids content was determined by refractometer as per AOAC method 932.12 (AOAC, 1995). Titratable acidity was assessed according to AOAC Method 920.149 (c) (AOAC, 1995) in which saskatoon fruit (20 g) were boiled for 1 hour and then centrifuged at 8500 rpm for 15 minutes. The resulting supernatant was filtered through Whatman #4 filter paper and made up to 250 mL, 200 mL of which was titrated. Titratable acidity was calculated as percent malic acid.

Colour characteristics were determined for the years 1999 and 2000 from fruit harvested from both sites. Colour measurements were conducted on the extracted fruit juice rather than on the fruit surface. Previous research (not presented here) on fruit colour determination of the fruit exterior produced large deviations in the results; the primary cause was probably due to light reflectance at numerous angles off the rounded fruit surfaces during measurement. Visually undetected differences in fruit maturity, and variations in the waxy cuticle layer surrounding the fruit also may have added to the variability. Therefore, subsequent measurements of colour were conducted on extracted fruit juice. Juice was extracted from the fruit in the same manner as for pH and soluble solids determination for colour measurements with the Miniscan XE colourimeter (Hunter Assoc., Reston, VA). The hue angle ($\tan^{-1}(b/a)$) and chroma ($(a^2 + b^2)^{0.5}$) were calculated to determine the colour and vividness of the fruit juice, respectively. The Hunterlab L value indicates the degree of lightness of the juice.

Fruit anthocyanin content was determined from fruit harvested in 1999 and 2000 from the U of S site only. Extracts were prepared for anthocyanin analysis by blending 20 g of thawed fruit with an extracting solvent of 50 mL of 0.1% HCl in methanol. The mixture was stored at 4°C overnight, then filtered through Whatman #4 filter paper. The resulting cake was rinsed with approximately 200 mL of the extracting solvent. The filtrate was made up to 250 mL with extracting solvent. Extracts were stored at -40°C. Prior to HPLC injection, extracts were filtered through 0.45 μm filters.

HPLC analysis of anthocyanin extracts was performed using a Waters Chromotograph gradient component system (Milford, MA) equipped with a Waters 600E multisolvent delivery system, Waters 717 plus autosampler, and a Waters 996 photodiode array detector. A 5μL injection of extract was separated on a NovaPak C18 column (4 μm, 3.9 X 150 mm, 3.9 X 20 mm NovaPak Sentry guard column; Waters, Milford, MA). The solvents used for component separation were 10% formic acid in water (solvent A) and 0.1% HCl in methanol (solvent B) (Kalt et al., 1999). The elution profile was as follows: linear gradient 0-20 min, 10-65% B; linear gradient 20-25 min, 65-100% B; and isocratic 25-30 min, 100% B (Extrasynthese, Genay, France). The flow rate was 1 mL/min and absorbance data were collected at 520 nm. Standard curves were generated by injecting different volumes of standard solutions of the anthocyanins cyanidin-3-galactoside (42 ng/μL) (Extrasynthese, Genay, France) and cyanidin-3-glucoside (41.6 ng/μL) (Extrasynthese, Genay Cedex, France). These standards were used because cyanidin 3-galactoside and cyanidin 3-glucoside were found to account for about 61% and 21% of the total anthocyanin content in saskatoons, respectively (Mazza, 1986). Amounts of the anthocyanins in the saskatoon fruit were determined from the standard curve, with unidentified anthocyanins calculated as cyanidin-3-galactoside.

Statistical analyses was conducted on the sub-sample means. Data were checked for normality prior to analysis. Analysis of variance was accomplished using the mixed model procedure (Proc Mixed) of SAS Version 6.11 (SAS Institute, Cary, NC). Site and/or year were considered as random factors. Mean separation among cultivars was accomplished using the least significant difference (LSD) test. Pearson correlation coefficients between anthocyanin content and the other fruit quality parameters were calculated using SYSTAT Version 8.0 (SPSS, Chicago, IL).

Results and Discussion

Fruit of the cultivars differed significantly in their 10 fruit weight, total solids, soluble solids, anthocyanin content, pH, titratable acidity, and in their ratio of soluble solids to titratable acidity. The colour of the fruit juice extracts differed among the cultivars in their chroma and L values, but not in their hue angle.

Ten fruit weights of the cultivars ranged from 7.9 to 16.6 g (Table 1). The 10 fruit weights of the cultivars Martin, Thiessen and PAR 90 (mean = 16.3 g) were significantly greater than all the other cultivars. JB30 also had a high fruit weight (13.5 g), whereas Success and Bluff (although not significantly different from Pembina and Buffalo) had the lowest 10 fruit weights (mean = 7.9 g). These findings are consistent with previous data reported on these cultivars from this trial on fruit size (Zatylny et al., 2002). Fruit of Pembina and Nelson had significantly higher levels of total solids and soluble solids than those of all the other cultivars (Table 1). Total solids and soluble solids contents ranged from 19.9% and 14.0 °Brix, respectively for JB30, to 27.9% and 20.1 °Brix, respectively for Pembina. Fruit pH ranged from 3.65 to 4.18, and was highest for the cultivars Parkhill, Smoky, Forestburg, and Pearson II (mean = 4.17) although not significantly different from that of Honeywood (Table 1). The pH of the fruit of Nelson, PAR 90, Martin, Thiessen, JB30 and Northline was lower than that of all the other cultivars and ranged in value from 3.65 for Nelson to 3.78 for Northline. Titratable acidity ranged from 0.29 % to 0.63 % (Table 1). Fruit of Nelson had the significantly highest titratable acidity (0.63 %) among the cultivars with an acidity level approximately twice that of the fruit of Success, Pearson II, Forestburg, Honeywood, Smoky and Parkhill, which had the lowest titratable acidity (mean = 0.31 %). Green and Mazza (1986) found similar values of titratable acidity for the fruit of Smoky and Northline, but lower values for Honeywood.

The ratio of fruit soluble solids to titratable acidity (SS/TA) differed greatly among the cultivars ranging from 26.9 to 55.4 (Table 1). Fruit of Parkhill, Success, Pearson II, Smoky, and Honeywood had SS/TA ratios 73% higher on average than those of JB30, Par90, Martin, Nelson, Thiessen, Northline, and Bluff. This latter group of cultivars likely would have a longer shelf-life due to their lower SS/TA ratios. The low SS/TA ratios of these cultivars were primarily due to their higher acidity. The values found in this study were similar to that found for saskatoons by Green and Mazza (1986) for the cutlivars Honeywood, Smoky and Northline. In general, the SS/TA ratios of saskatoon fruit were found to be much higher than those found in blueberries due to the lower acidity levels of saskatoons (Galletta et al., 1971; Ballington et al., 1984; Ballinger et al., 1978). However, this may also be partially associated with the stage of ripeness that blueberries are harvested. Blueberry fruit that were fully ripe or overripe had acidity and SS/TA ratios in ranges similar to that found in the fully ripe saskatoons assessed in this study (Ballinger et al., 1978). Galleta et al. (1971) found that blueberries high in acidity or with low soluble solids to acid ratios could be stored for longer periods. Ballinger and Kushman (1970) concluded that fruit high in acidity tend to have a better fresh fruit keeping quality because the acidity inhibits the growth of fruit rotting organisms. Ballinger et al. (1978) also calculated that blueberries with SS/TA ratios greater than 30 did not store well and should be processed.

Although this ratio may be different for saskatoons, it is conceivable that fully ripe saskatoons may not be suitable for the fresh market due to a more limited shelf-life and may need to be sorted out prior to marketing.

The colour characteristics of the extracted fruit juice of the cultivars are presented in Table 2. No differences in fruit juice colour hue existed among the cultivars. Chroma values ranged from 23.6 for fruit juice of Success to 34.1 for that of Martin. L values of the fruit juice ranged from 14.8 for Bluff to 21.8 for Martin. The cultivars Martin, Thiessen, PAR 90 and JB30 were among those cultivars with the most vivid and lightest fruit juice colour as represented by high chroma values (mean = 33.4) and high L values (mean = 21.4), respectively. Colour analysis of the extracted fruit juice yielded consistent results in contrast to previous colour measurements of the fruit exterior. The colour of the fruit juice extract will be directly applicable to any final products produced from fruit juice and to products in which the juice leaches out of the fruit such as jams and pie fillings.

Anthocyanin content for the fruit of the various cultivars is presented in Table 3. Four peaks were found at 520 nm (Figure 1). The first was identified as cyanidin-3-galactoside and the second as cyanidin-3-glucoside. The remaining two peaks were not identified. Cyanidin-3-galactoside consistently accounted for the largest percentage of total peak area, followed by cyanidin-3-glucoside, then unknown 1 and unknown 2. Total fruit anthocyanin content ranged from 414 to 852 μg/g. Fruit of Nelson and Bluff had the highest total anthocyanin content (mean = 815 μg/g), followed by that of Northline (699 μg/g). The fruit of Bluff and Nelson were also the highest among the cultivars for the different types of anthocyanins found, cyanidin-3-galactoside, cyanidin-3-glucoside, and for the two unknown peaks. However, the high total anthocyanin content for the fruit of Northline was primarily due to the large amounts of cyanidin-3-galactoside; Northline had the lowest cyanidin-3-glucoside content of the cultivars. The total anthocyanin contents were lower than those reported by Green and Mazza (1986) for fruit of the cultivars Honeywood, Smoky and Northline. The discrepancy may be due, at least in part, to differences in methodology. Green and Mazza (1986) employed the pH differential method of Fuleki and Francis (1968) to determine total anthocyanin content. It was expected that the spectrophotometric method of Fuleki and Francis (1968) would produce larger values due to the absorbance of other compounds and the use of only one molar extinction coefficient. The HPLC method employed in this study was considered more accurate in this respect. However, total anthocyanin contents measured in this study may be low because the absorbance of anthocyanins at wavelengths other than 520 nm was not determined.

Significant correlations were found between anthocyanin content and fruit pH ($r = -0.41$, $p<0.001$), titratable acidity ($r = 0.53$, $p<0.001$), hue angle ($r = -0.43$, $p<0.001$) and Hunterlab L value ($r = -0.31$, $p=0.038$). The greater the fruit acidity, the higher was the anthocyanin content. Fruit producing darker (lower L value), more purple (lower hue angle) juice were also associated with a higher anthocyanin content. Similar correlations were previously found in saskatoons between anthocyanin content and fruit pH, acidity, and hue angle (Green and Mazza, 1986).

Anthocyanin content is largely responsible for the colour of the fruit skin and flesh and thus influences the marketability of the fruit. Anthocyanins are vulnerable to degradation during processing and storage (Perera and Baldwin, 2001). A reduction in anthocyanin content has been observed during the cold storage of saskatoon fruit (Rogiers and Knowles, 1998, 2000). Rogiers and Knowles (2000) reported the greatest reduction in anthocyanin content of saskatoons (cvs. Northline, Smoky, Pembina and Thiessen) to occur within the first 11 days of cold storage at 0.5°C. Fruit high in anthocyanin content may be desirable to ensure that minimum acceptable levels remain after loss through storage or processing. In general, the anthocyanin content of saskatoon fruit was found not to be as high as in blueberries. Anthocyanin contents determined for blueberry by HPLC method ranged from 830 to 2550 μg/g FW (Kalt et al., 1999) and from 1093 to 2607 μg/g FW (Gao and Mazza, 1994).

Of the cultivars evaluated in this study, Nelson stands out as having a high total and soluble solids content, high acidity, a low SS/TA ratio, low pH, and high anthocyanin content suggesting that this cultivar may be the most suited for storage for fresh consumption and for processing where a high total solids content is desirable to maximize usable product. However, the cultivars most desirable for fresh fruit consumption are largely determined by their flavour, fruit size and appearance. It has been noted that the fruit of Nelson, in spite of having superior physicochemical properties, did not have the most appealing flavour when eaten fresh. Nelson also produced smaller fruit than a number of other cultivars. For these reasons, fruit of Nelson may be better suited for processing. Fruit of JB30, Par90, Martin, Thiessen and Northline all had low SS/TA ratios indicating that they may have good storage properties. The fruit of these cultivars are larger in size than that of Nelson and have been noted as having good flavour when eaten fresh. Nevertheless, further research is required to determine which cultivars are best suited for fresh consumption based on storage studies and sensory evaluations of fresh fruit. Likewise, the assessment of processed fruit products of the various cultivars needs to be conducted before determining which cultivars produce fruit most suited for processing.

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Table 1. Fruit physicochemical characteristics of saskatoon cultivars harvested from Moonlake, SK and the University of Saskatchewan (U of S), Saskatoon, SK in 1998-2000.

Cultivar	10 Fruit Weight (g)	Total Solids (%)	Soluble Solids (°Brix)	pH	Titratable Acidity[1] (% Malic Acid)	SS/TA[2]
Bluff	8.0 a[3]	20.9 abc	14.5 ab	3.97 d	0.435 bc	33.0 ab
Buffalo	9.5 abc	22.6 cd	16.5 bc	4.00 d	0.420 b	38.8 bc
Elizabeth	N/A[4]	N/A	N/A	N/A	0.464 bcde	N/A
Forestburg	11.4 d	20.6 abc	15.3 abc	4.17 f	0.308 a	45.8 cd
Honeywood	10.7 cd	21.7 abcd	15.8 abc	4.14 ef	0.311 a	49.7 de
JB30	13.5 e	19.9 a	14.0 a	3.78 c	0.495 cdef	26.9 a
Martin	16.6 f	20.8 abc	15.3 abc	3.71 b	0.519 def	29.8 a
Nelson	10.3 cd	25.1 e	18.8 de	3.65 a	0.631 g	30.3 a
Northline	10.6 cd	23.0 d	16.5 bc	3.78 c	0.529 ef	32.7 ab
PAR 90	15.9 f	20.9 abc	15.1 abc	3.70 ab	0.534 f	28.0 a
Parkhill	9.7 bc	22.6 cd	17.2 cd	4.18 f	0.321 a	55.4 e
Pearson II	11.1 cd	21.4 abcd	15.8 abc	4.16 f	0.301 a	52.5 de
Pembina	8.5 ab	27.9 f	20.1 e	3.95 d	N/A[5]	N/A[5]
Smoky	10.9 cd	21.5 abcd	16.0 abc	4.18 f	0.312 a	49.8 de
Success	7.9 a	21.9 bcd	15.3 abc	4.09 e	0.291 a	53.9 de
Thiessen	16.2 f	20.4 ab	14.8 ab	3.76 bc	0.455 bcd	31.4 ab
Mean	11.4	22.1	16.1	3.95	0.422	39.9
Standard Error[6]	0.66	0.80	1.04	0.046	0.023	4.36

[1] Titratable acidity was analysed from fruit only from the U of S site and for the years 1999 and 2000

[2] Soluble solids to titratable acidity (SS/TA) ratio calculated only for the UofS site for the years 1999 and 2000

[3] Means within a column followed by the same letter are not significantly different using LSD ($p < 0.05$)

[4] Elizabeth was not grown at the Moonlake site and was excluded from the statistical analysis of the 2 sites together

[5] Pembina was deleted from the statistical analysis due to missing data as a result of insufficient fruit in 2000

[6] Standard error of the mean

Table 2. Colour characteristics of the fruit juice of saskatoon cultivars harvested from sites at Moonlake, SK and the University of Saskatchewan (U of S), Saskatoon, SK in 1999 and 2000.

Cultivar[1]	Hue Angle (°)	Chroma	L
Bluff	17.5	25.9 ab[2]	14.8 a
Buffalo	16.8	27.4 abc	14.9 a
Forestburg	19.7	28.1 bc	19.4 bcde
Honeywood	19.4	27.5 abc	18.5 abcde
JB30	18.5	32.5 d	21.4 de
Martin	18	34.1 d	21.8 e
Nelson	17.3	31.5 cd	16.4 ab
Northline	17.9	30.7 cd	17.6 abcd
PAR 90	18.1	33.3 d	20.5 cde
Parkhill	17.4	26.3 ab	15.4 ab
Pearson II	19.3	28.1 bc	18.5 abcde
Pembina	18.2	27.7 abc	17.0 abc
Smoky	19.7	27.2 abc	18.2 abcde
Success	20.2	23.6 a	15.6 ab
Thiessen	18.1	33.6 d	21.8 e
Mean	18.4	29.2	18.1
Standard Error[3]	0.94	2.00	1.32

[1] The cultivar Elizabeth was excluded from the statistical analysis as this cultivar was not grown at the Moonlake site.

[2] Means within a column followed by the same letter are not significantly different using LSD ($p \leq 0.05$).

[3] Standard error of the mean.

Table 3. Anthocyanin contents of the fruit of saskatoon cultivars harvested from the University of Saskatchewan (U of S), Saskatoon, SK site in 1999 and 2000.

Cultivar	Peak 1 Cyanidin-3-Galactoside (µg/g)	Peak 2 Cyanidin-3-Glucoside (µg/g)	Peak 3 Unidentified[1] (µg/g)	Peak 4 Unidentified (µg/g)	Total Anthocyanin Content (µg/g)
Bluff	454 e[2]	159.4 d	91.9 d	71.6 c	777 gh
Buffalo	344 d	148.6 cd	76.7 c	70.1 c	639 ef
Elizabeth	255 abc	111.1 ab	63.1 ab	54.5 ab	484 abcd
Forestburg	205 a	97.6 ab	60.0 ab	51.2 a	414 a
Honeywood	227 ab	96.7 ab	60.1 ab	51.6 ab	435 ab
JB30	326 cd	124.0 bc	69.7 bc	60.2 b	580 def
Martin	316 cd	116.9 ab	64.5 b	56.2 ab	554 bcde
Nelson	509 e	172.9 d	94.3 d	75.4 c	852 h
Northline	483 e	88.6 a	70.7 bc	56.9 ab	699 fg
PAR 90	324 cd	125.3 bc	65.6 bc	59.6 ab	574 cde
Parkhill	295 bcd	114.2 ab	62.4 ab	57.0 ab	529 abcde
Pearson II	216 a	96.6 ab	60.6 ab	51.3 a	424 a
Smoky	231 ab	103.4 ab	63.5 b	53.9 ab	452 abc
Success	261 abc	91.7 a	52.1 a	52.7 ab	457 abcd
Thiessen	256 abc	111.6 ab	62.0 ab	54.7 ab	466 abcd
Mean Standard Error[3]	31324.6	117.2 9.51	68.0 3.69	54.5 2.83	55640.4

[1] Amount of unknowns were calculated as cyanidin-3-galactoside.

[2] Means within a column followed by the same letter are not significantly different using LSD ($p \leq 0.05$).

[3] Standard error of the mean.

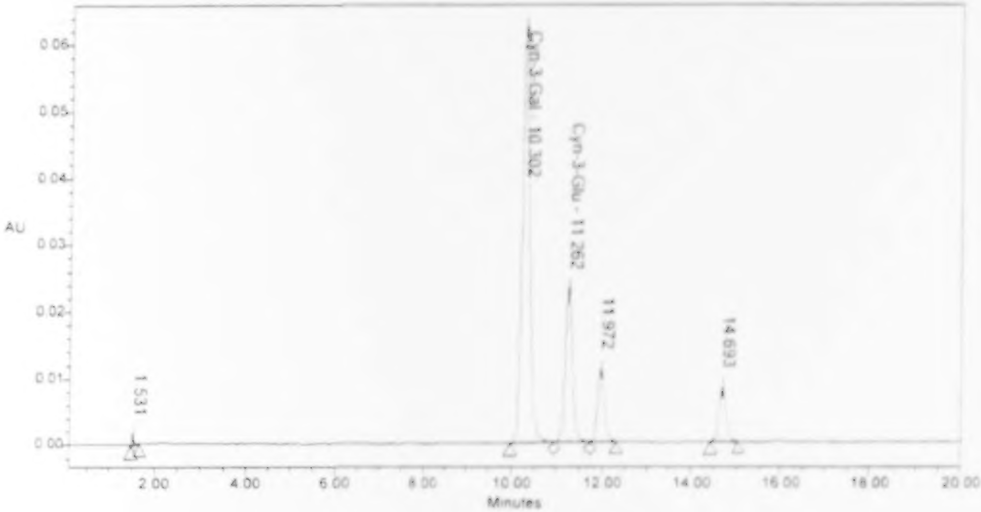

Figure 1. An example of a chromatogram showing the anthocyanin profile of saskatoon fruit.

The agronomic performance of chokecherry, pincherry, highbush cranberry and black currant cultivars evaluated in Saskatchewan

R.G. St-Pierre, A.M. Zatylny and H.P. Tulloch

Abstract

A number of native fruit cultivars, chokecherry (*Prunus virginiana* L.), pincherry (*Prunus pensylvanica* L.f.) and highbush cranberry (*Viburnum trilobum* Marsh.), as well as cultivars of black currant (*Ribes nigrum* L.) were evaluated in replicated trials at two sites (Saskatoon and Outlook) in Saskatchewan over four years. Espenant, Garrington, Lee Red and Boughen Yellow were the highest yielding of the chokecherry cultivars (mean yield = 5.8 kg/plant at Sasktoon). The chokecherry cultivars Goertz, Lee Red, Robert, Copper Schubert, and Espenant had the largest fruit size (mean= 210 fruit/cup at Saskatoon). The pincherry cultivar Lee #4 (mean yield = 3.1 kg/plant) yielded twice as much or more than Mary Liss or Jumping Pound. The pincherry cultivars did not differ in their fruit size. Highbush cranberry cultivars Garry Pink, Manitou and Wentworth were among those with the highest yields (mean = 2.0 kg/plant at Saskatoon). Of these, Manitou had significantly larger fruit than Wentworth and Garry Pink. In general, black currant production was low with good yields occurring in only one out of four years; this variable production was attributed to the climate. Black currant yields ranged from 0.2 kg/plant for Willoughby to 1.0 kg/plant for Consort in the first trial, and from 0.2 kg/plant for the selection 4-24-29 to 2.0 kg/plant for McGinnis Black in the second trial. Black currant cultivars with the largest fruit size included Wellington, Topsy, and three selections from the University of Saskatchewan (mean=225 fruit/cup) in the first trial, and Ben Sarek, McGinnis Black, and Ben Alder (mean=156 fruit/cup) in the second trial.

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Introduction

In recent years, a large focus has been placed on investigating alternative crops to diversify the agriculture and economy of the Canadian prairies. Amongst these were a number of fruit species native to this region (chokecherry, pincherry and highbush cranberry) and black currants. Cultivars of these native fruits have never been evaluated in replicated cultivar trials, and all previous information has been obtained from observational or unreplicated data. Likewise, black currant cultivar recommendations for the prairies have been primarily based on their ability to overwinter. Thus, the University of Saskatchewan has established replicated cultivar trials of these fruits for evaluation as potential new horticultural crops for the prairies.

The chokecherry (*Prunus virginiana* L.) and pincherry (*Prunus pensylvanica* L.f.) are shrubs or small trees native across Canada, north to the boreal forest and throughout most of the United States (Hall et al., 1981; Vilkitis, 1974). Both are true cherries and a close relative of the domesticated cherries. The highbush cranberry (*Viburnum trilobum* Marsh.) is a member of the honeysuckle family (Caprifoliaceae). This native shrub is found north to Alaska and from coast to coast throughout southern Canada and the northern United States (Stang, 1990). The fruits of the chokecherry, pincherry and highbush cranberry were widely used by North American Indians and early settlers (Stang, 1990; Wilkinson, 1990). The fruit are still used today for jellies, syrups and beverages. Cultivars of these three native fruits have been selected from wild stands and are now grown under cultivation; breeding of these fruits has never been undertaken. A number of black currant (*Ribes nigrum* L.) cultivars are very winter hardy and may be suited for production on the prairies. Very few black currant cultivars have been grown in Saskatchewan and none have been formally tested.

The objective of this study was to evaluate selected cultivars of chokecherry, pincherry, highbush cranberry and black currant for their agronomic characteristics. This research will provide a basis upon which the agronomic characteristics of any new selections may be compared, and from which growers can choose cultivars for production.

Materials and Methods

Cultivar evaluation trials of chokecherry, pincherry, highbush cranberry and black currants were established at two sites in Saskatchewan, at Saskatoon within the University of Saskatchewan field plots, and at Outlook. These trials consisted of three blocks in a completely randomized design at each site. Five plants per cultivar were planted in each block. All plants were propagated by cuttings or tissue culture and planted as one year old plants. The plants were planted at spacings of 1 m within the rows and 3 m and 4.5 m between the rows for black currants and the other native fruits, respectively.

Chokecherry cultivars evaluated included BoughenYellow, Copper Schubert, Garrington, Goertz, Lee Red, Mission Red, Robert and Espenant, a selection from a grower near Hudson Bay, SK. Only Boughen Yellow, Garrington and Lee Red were planted at Outlook. All cultivars were planted in the fall of 1994 at both sites except Copper Schubert, Mission Red, and Espenant which were planted in the fall of 1995.

Pincherry cultivars evaluated at both sites included Jumping Pound, Lee #4, and Mary Liss. All were planted in the fall of 1994.

Highbush cranberry cultivars evaluated included Alaska, Andrews, Garry Pink, Manitou, Phillips, Wentworth and Espenant, a selection from a grower near Hudson Bay, SK. Only Alaska, Phillips, and Wentworth were planted at Outlook. All highbush cranberry cultivars were planted in the fall of 1994 except for Espenant, which was planted in the fall of the following year.

Two black currant cultivar trials were established at Saskatoon. Black currant cultivars evaluated in the first trial included Boskoop Giant, Consort, Coronet, Crusader, Magnus, Topsy, Wellington, Willoughby, and three open-pollinated selections of Öjebyn from the University of Saskatchewan (5-24-9, 5-23-42 and 25-23-23). The cultivars Consort, Wellington and Willoughby were planted at Outlook. These cultivars were planted in the fall of 1994 at both sites. A second black currant trial was established at Saskatoon in the spring of 1998. Black currant cultivars in this trial included Ben Alder, Ben Lomond, Ben Nevis, Ben Sarek, Consort, Crusader, Magnus, McGinnis, Noir de Bourgogne, Titania, Wellington, and an open-pollinated selection of Öjebyn from the University of Saskatchewan (4-24-29). McGinnis Black is a selection from the SCRI breeding program that was named and propagated by McGinnis Berry Crops nursery in BC?

The trials were irrigated by drip irrigation. All weeds were controlled manually and by cultivation. Leaf roller caterpillars in chokecherries and black currants were controlled by insecticides in 2000 and 2001. Fruit were manually harvested from one to three plants per cultivar from each replicate. The currant season's shoot growth were recorded in late summer from five randomly selected shoots from each of the three middle plants within a plot. The number of new suckers per plant from the three middle plants within a plot were recorded for chokecherries in 1999-2001.

Cultivar data were analysed using SAS Proc Mixed (SAS Institute, Cary, NC) in which site and year were considered to be random factors. Data were checked for normality prior to statistical analysis and transformed if necessary by square root. Cultivar mean separation was accomplished by LSD.

Results and Discussion

Chokecherry

The chokecherry plants did not produce significant amounts of fruit until 1999, however, the cultivars Boughen Yellow and Garrington appeared to be more precocious and produced some fruit in 1998 at both sites (mean yield = 0.43 and 0.19 kg/plant for Boughen Yellow and Garrington, respectively). The chokecherry plants appeared to have reached their mature yielding capacity by 2002 as indicated by the lack of a further yield increase in 2003 (Figure 1). At Saskatoon from 2000-2003, Espenant was the highest yielding of the cultivars followed by that of Garrington, Lee Red and Boughen Yellow. Espenant yielded 1.9 to 2.8 times more fruit than that of Copper Schubert, Goertz, Mission Red, and Robert (Table 1). The three chokecherry cultivars at Outlook did not differ in their yield.

Fruit size differed among the cultivars at both sites (Table 1). At Saskatoon, Mission Red had significantly smaller fruit than all the other cultivars; Goertz had significantly larger fruit by 18-35% than Garrington, Boughen Yellow and Mission Red. At Outlook, the fruit of Boughen Yellow were significantly smaller than that of Garrington and Lee Red by 17-38%.

Differences in shoot growth were found amongst the cultivars at Saskatoon, but not at Outlook. At Saskatoon, Copper Schubert had 23-53% greater shoot growth than all of the other cultivars (Table 1). Robert also had a greater shoot growth than Garrington at this site. Yearly shoot growth decreased as the plants matured (Figure 2). Sucker production did not differ among the chokecherry cultivars at either site. An average of 1.4 and 2.6 suckers/chokecherry plant were produced at Saskatoon and Outlook, respectively, from 1999-2001 (data not shown).

Pincherry

Pincherry yield differed among the three cultivars. At both sites, Lee #4 yielded twice as much or more than that of Mary Liss or Jumping Pound (Table 2). The pincherries at Saskatoon were more precocious, producing 9% of their mature yield in1997, and 16% in 1998, whereas pincherry fruit yields at Outlook in these two years were not worth harvesting. The maximum yield of pincherry occurred in 1999 (Figure 1). Fruit size or shoot growth did not differ significantly among the cultivars at both sites.

Highbush Cranberry

A few of the highbush cranberry cultivars produced fruit in 1999; these included Alaska, Garry Pink, Manitou, and Wentworth (Mean yield = 1.56 kg/plant). No further increase in yearly yields of highbush cranberry occurred after 2002, possibly indicating that its mature yields had been attained (Figure 1). Of the highbush cranberry cultivars, Phillips at both sites was never harvested due to bearing almost no fruit. The cultivar Andrews at Saskatoon also yielded very little fruit: it was only harvested in 1999 and 2000 (mean yield = 0.37 kg/plant), and therefore, was not included in the statistical analysis. The poor fruit yield of Andrews could be attributed, in part, to extensive mite damage that occurred on this cultivar. At Saskatoon, Garry Pink, Wentworth and Manitou yielded 1.8 to 2 times more fruit than Espenant (Table 3). At Outlook, the highbush cranberry cultivar, Wentworth yielded 35% more fruit than that of Alaska, whereas at Saskatoon, the yields of these two cultivars did not differ significantly.

Cultivars differed in fruit size at Saskatoon with Espenant having the significantly smallest fruit of all the cultivars (Table 3). Manitou had significantly larger fruit than Wentworth, Garry Pink and Espenant at this site. Manitou was originally selected from wild stands in Manitoba for its large fruit size (Darrow, 1975). The fruit size of Wentworth and Alaska did not differ at Outlook, nor at Saskatoon.

Yearly shoot growth did not differ among the cultivars at Outlook, however at Saskatoon, the shoot growth of Manitou was 26 and 50% greater than that of Espenant and Andrews, respectively (Table 3).

Black Currant

Trial 1

The first black currant cultivar trial came into production in 1999. Although the cultivars at Outlook produced significant amounts of fruit in 1998 (mean yield = 0.48 kg/plant), negligible amounts of fruit were produced at Saskatoon that year. Cultivar differences in yield from 1999-2002 were found at Saskatoon but not at Outlook (Table 4). At Saskatoon, Boskoop Giant yielded enough fruit (mean yield = 0.36 kg/plant) to be harvested in 2000, however it was not harvested in any of the other years due to its very low fruit production and so was not included in the statistical analysis. At Saskatoon, Consort, 5-23-42 and Wellington produced on average 3.8 times significantly greater yields than 5-24-9 and Willoughby. The yields of Consort, Wellington and Willoughby did not differ significantly at Outlook. At Saskatoon, Willoughby yielded significantly less than Wellington, but the yield of these two cultivars was not significantly different at Outlook. Nevertheless, at Outlook, Wellington yielded almost 3 times more fruit than Willoughby; this difference was probably not significant due to the small experimental size at this site.

Fruit size differed greatly from year to year. For example, Wellington from one plot at Saskatoon had 108 fruit per cup in 1999, but 446 fruit per cup in 2002. Fruit size differed significantly at both sites (Table 4). At Outlook over the four years, the fruit size of Wellington, Willoughby and Consort all differed from each other with Wellington having the largest fruit and Consort, the smallest. The cultivars at Saskatoon with the largest fruit size included 5-23-42, 25-23-23, Wellington, 5-24-9, and Topsy (mean = 225 fruit/cup). Fruit size of the selections 5-23-42 and 25-23-23 was significantly larger than that of Consort, Coronet, and Crusader by 71%. Although the number of fruit/cup differed between Wellington and Consort at Outlook, these two cultivars did not differ in fruit size at Saskatoon.

Average yearly shoot growth over the four years did not differ among the cultivars at Saskatoon nor at Outlook, but decreased as the plants matured (Figure 2). Mean shoot growth at Saskatoon and at Outlook were 19.4 cm and 18.2 cm, respectively from 1999-2002.

Trial 2:

The black currant cultivars in the second trial did not produce significant quantities of fruit until 2000. However, the more precocious of the cultivars did produce some fruit in 1999. These cultivars included Ben Alder, Ben Nevis, Ben Sarek, and McGinnis Black. Ben Nevis yielded an average of 0.64 kg/plant that year while the other cultivars produced an average of 0.13 kg/plant. The black currant cultivars in the second trial established at Saskatoon differed significantly in their yield (Table 5). The cultivars McGinnis Black and Ben Nevis (mean yield = 1.87 kg/plant) had significantly greater yields than 4-24-29, Noir de Bourgogne, Titania, Magnus, Crusader, Consort, and Wellington (mean yield = 1.18 kg/plant). The Scottish 'Ben' types have outyielded a number of other black currant cultivars in previous studies (Muster and Roser, 1993; Dale et al., 1993). Titania has produced high yields comparable to that of the 'Ben' types in yield trials in Poland and Norway (Pluta and Zurawicz, 1993; Nes, 1993; Muster and Roser, 1993; Pluta et al, 1993). However, in this study Titania produced 30-45% less fruit than the 'Ben' types in these trials.

Ben Sarek and McGinnis Black had the largest fruit size (mean = 145 fruit/cup) followed by that of Ben Alder, Ben Nevis, Wellington and Titania (mean = 183 fruit/cup) all which did not differ significantly from that of McGinnis Black (Table 5). Consort, Crusader and Noir de Bourgogne were among the smallest fruiting of the cultivars (mean = 269 fruit/cup).

Yearly shoot growth did not differ significantly among the cultivars (data not shown). Mean shoot growth from 2001-2003 of the cultivars in this second trial was 25.3 cm.

Black currants cultivars in both trials experienced large yearly fluctuations in yield (Figure 2). The highest yields occurred in 1999 for the first trial and in 2003 for the second trial. Years of below-normal yields were most likely due to premature fruit drop. This condition can occur approximately 3 weeks after flowering and can cause major yield losses in black currant

(Brennan, 1990). Unfavourable environmental conditions, such as low but above zero temperatures during flowering (Dale, 1984) can increase premature fruit drop. The cultivar Magnus in particular has been reported to be very susceptible to premature fruit drop due to low temperatures during flowering (Dale, 1984). This however, does not explain the yearly variations in yield in this study as yields were high in 2003 in spite of temperatures being quite cool during the week that the black currants blossomed that spring. Although other factors have been implicated to increase premature fruit drop, such as insufficient fertilization and post-harvest drought in the previous season, there is no direct evidence to support this relationship (Brennan, 1990). In this study, there was also no association with post-harvest moisture conditions and yield in the following season. In general, black currants prefer cool, moist conditions (Barney, 1996). The spring of 1999, a high-yielding year, was cooler than normal with above average rainfall, which may account for the higher yields obtained in this year. However, cool and moist conditions did not account for the high yields in 2003 which experienced above average temperatures and below average rainfall in spring. It is possible that black currants in the second trial could have been just coming into full production in 2003 which may have accounted for its higher yields in this year compared to previous years. Nevertheless, it appears that the conditions that dictate a high yielding year for black currants are complex and not solely a factor of spring weather conditions.

Conclusions

A number of the native fruit cultivars evaluated in this study proved to be superior in yielding capacity and/or fruit size. This information was not previously available and will provide a basis for cultivar selection of these fruits by growers. Of the chokecherry cultivars evaluated, the high yielding capacity of the selection, Espenant, warrants further attention. Garrington and Lee Red also proved to be more productive of the chokecherry cultivars. The large fruit size of Goertz makes this chokecherry cultivar attractive for both fresh consumption and processing. Of the pincherry cultivars evaluated, Lee #4 stood out as being very productive. The highbush cranberry cultivars, Garry Pink, Wentworth and Manitou produced good yields. Of these three, Manitou also had large fruit.

Of the black currants cultivars evaluated, McGinnis Black, Ben Nevis, Wellington and the selection 5-23-42 were high yielding with large fruit. However, black currant production in Saskatchewan will probably always be highly variable producing inconsistent and often poor yields due to the unsuitable climate. Until the breeding and selection of black currants that can better tolerate the prairie climate, commercial production of black currants in Saskatchewan may not be feasible.

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Table 1. Mean fruit yield, fruit size and shoot growth of chokecherry cultivars grown at Saskatoon and Outlook from 2000-2003.

Cultivar	Saskatoon			Outlook		
	Yield (kg/plant)	Number of Fruit per Cup	Shoot Growth (cm)	Yield (kg/plant)	Number of Fruit per Cup	Shoot Growth (cm)
Boughen Yellow	4.95 abcd[1]	245 c	24.0 ab	3.7	287 a	20.5
Copper Schubert	3.72 abc	214 abc	34.3 c			
Espenant	7.17 d	229 abc	26.7 ab			
Garrington	5.92 cd	238 bc	22.4 a	5.01	256 a	21.3
Goertz	3.32 ab	194 a	25.9 ab			
Lee Red	5.12 abcd	203 ab	25.6 ab	4.45	208 a	22.6
Mission Red	2.91 ab	299 d	24.4 ab			
Robert	2.58 a	211 abc	27.9 b			
Standard Error	0.939	13.1	9.08	1.283	20.8	3.13

[1] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 2. Mean fruit yield and fruit size of pincherry cultivars from 1999-2003 at Saskatoon and 1999-2002 at Outlook.

Cultivar	Saskatoon		Outlook	
	Yield (kg/plant)	Number of Fruit per Cup	Yield (kg/plant)	Number of Fruit per Cup
Jumping Pound	1.55 a[1]	229	1.35 a	276
Lee #4	3.08 b	224	3.13 b	259
Mary Liss	1.56 a	238	1.15 a	NA[2]
Standard Error	0.237	24.5	0.672	31.4

[1] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

[2] Data not available.

Table 3. Mean fruit yield, fruit size and shoot growth of highbush cranberry cultivars grown at Saskatoon and Outlook from 2000-2003.

Cultivar	Saskatoon			Outlook		
	Yield (kg/plant)	Number of Fruit per Cup	Shoot Growth (cm)	Yield (kg/plant)	Number of Fruit per Cup	Shoot Growth (cm)
Alaska	1.67 ab[1]	222 ab	32.5 bc	0.79 a	263	33.4
Andrews	NA[2]	NA	24.2 a			
Espenant	1.02 a	310 c	29.0 ab			
Garry Pink	2.07 b	252 b	32.4 bc			
Manitou	1.92 b	212 a	36.4 c			
Phillips	NA	NA	32.1 bc	NA	NA	37.8
Wentworth	2.04 b	247 b	30.7 abc	1.07 b	281	33.2
Standard Error	0.277	15.1	3.88	0.209	32.7	4.88

[1] Means within a column followed by the same letter are not significantly different at P≤0.05.

[2] Data not available.

Table 4. Mean fruit yield and fruit size of black currant cultivars (Trial 1) at Saskatoon and Outlook from 1999-2002.

Cultivar	Saskatoon		Outlook	
	Yield (kg/plant)	Number of Fruit per Cup	Yield (kg/plant)	Number of Fruit per Cup
39956	0.29 ab	248 abcd		
15483	0.95 c	187 a		
25-23-23	0.54 bc	189 ab		
Consort	0.99 c	304 cde	1.31	352 c
Coronet	0.62 bc	319 de		
Crusader	0.62 bc	341 e		
Magnus	0.61 bc	264 bcd		
Topsy	0.59 bc	261 abcd		
Wellington	0.94 c	239 abc	1.52	220 a
Willoughby	0.21 a	NA[z]	0.53	283 b
Standard Error	-0.236	56.6	0.633	19.4

[y] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

[z] Data not available.

Table 5. Mean fruit yield and fruit size of black currant cultivars (Trial 2) at Saskatoon from 2000-2003.

Cultivar	Yield (kg/plant)	Number of Fruit per Cup
47231	0.21 a[1]	202 cd
Ben Alder	1.14 bc	178 abc
Ben Lomond	1.11 bc	199 cd
Ben Nevis	1.74 c	180 bc
Ben Sarek	1.30 bc	138 a
Consort	0.54 ab	284 f
Crusader	0.54 ab	265 ef
Magnus	0.54 ab	236 de
McGinnis Black	2.00 c	152 ab
Noir de Bourgogne	0.30 a	257 ef
Titania	0.52 ab	190 bc
Wellington	0.66 ab	182 bc
Standard Error	(0.278)[2]	26.1

[1] Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

[2] The transformed standard error is presented in brackets when data were transformed prior to analysis. Backtransformed means are presented.

Physicochemical Properties of Fruit of Chokecherry (*Prunus virginiana* L.), Highbush Cranberry (*Viburnum trilobum* Marsh.), and Black Currant (*Ribes nigrum* L.) Cultivars Grown in Saskatchewan

A.M. Zatylny, W.D. Ziehl and R.G. St-Pierre

Abstract

Physicochemical properties of the fruit of chokecherry (*Prunus virginiana* L.), highbush cranberry (*Viburnum trilobum* Marsh.), and black currant (*Ribes nigrum* L.) were assessed from fruit harvested from replicated cultivar trials at Saskatoon, SK and at Yorkton, SK (black currants only) in 1999 and 2000. These fruits were being evaluated by the University of Saskatchewan as potential new horticultural crops for the Canadian prairies. Fruit weight, total solids, soluble solids, pH, titratable acidity (black currant only), percent pit and estimated percent flesh (chokecherry and highbush cranberry only) were measured. Hunterlab colour characteristics of the fruit juice extracts were also analyzed. Chokecherry cultivars evaluated included Boughen Yellow, Copper Schubert, Garrington, Goertz, Lee Red, Mission Red, and Robert. Fruit of the chokecherry cultivars ranged significantly in their 10 fruit weights from 6.6-9.2g, percent pit from 9.4-16.0%, estimated percent flesh from 17.2-23.7%, and pH from 3.86-4.25. Mean total solids and soluble solids contents were 35.2% and 18.3°Brix, respectively, and did not differ among the cultivars. Chokecherry colour characteristics of their fruit juice extracts ranged significantly in their hue angle, chroma and L values from 34.6-88.2°, 15.3-23.9, and 23.3-51.1, respectively. Highbush cranberry cultivars evaluated included Alaska, Andrews, Garry Pink, Manitou, and Wentworth. Fruit of the highbush cranberry cultivars ranged significantly in their 10 fruit weights from 4.1-7.3 g, percent pit from 4.6-9.0%, estimated percent flesh from 10.9-14.0%, soluble solids content from 10.2-13.3 °Brix, and pH from 2.89-3.13. The hue angle and L values of the fruit juice extracts of the highbush cranberry cultivars ranged significantly from 16.0-18.2°, and 15.5-21.3, respectively. Mean total solids content and L values were 18.9% and 18.0, respectively; both measurements did not differ significantly among the cultivars. Black currant cultivars evaluated included Boskoop Giant, Consort, Magnus, Topsy, Wellington, Willoughby, and three selections from the University of Saskatchewan. Fruit of the black currant cultivars differed only in their 10 fruit weight, pH and titratable acidity which ranged from 7.5-12.8 g, 2.85-3.04, and 3.04-4.03, respectively. Mean total solids and soluble solids contents of black currant fruit were 22.3% and 15.8 °Brix, respectively. Black currant fruit juice extracts had a mean hue angle, chroma and L values of 13.2°, 12.6 and 9.8, respectively.

Funding for this project was provided by Saskatchewan Agriculture and Food.

Introduction

The chokecherry (*Prunus virginiana* L.) is a shrub or small tree native to and widespread across Canada and most of the United States (Vilkitis, 1974). It is a true cherry and a close relative of the domesticated cherries. The highbush cranberry (*Viburnum trilobum* Marsh.) is a member of the honeysuckle family (Caprifoliaceae). This native shrub is found north to Alaska and from coast to coast throughout southern Canada and the northern United States (Stang, 1990). The fruits of both the chokecherry and highbush cranberry were widely used by North American Indians and early settlers (Stang, 1990; Wilkinson, 1990). The fruit are still used today for jellies, syrups and beverages. Superior selections of both chokecherry and highbush cranberry have been selected from wild stands and are now beginning to be grown under cultivation; breeding of these fruits has never been undertaken. A number of black currant (*Ribes nigrum* L.) cultivars appear to be very winter hardy and may be suitable for production on the Canadian prairies. Very few black currant cultivars have been grown in Saskatchewan and none have been formally tested. The need for agriculture diversification on the Canadian prairies has driven the evaluation of potential new horticultural crops including various native fruit species. Consequently, the Native Fruit Development Program at the University of Saskatchewan established replicated cultivar trials of these fruits for evaluation.

The objective of this study was to assess the fruit quality of a number of cultivars of chokecherry, highbush cranberry, and black currant presently under evaluation. Fruit physicochemical properties of chokecherry and highbush cranberry cultivars have not been previously published. This research will permit a direct comparison of fruit quality among the cultivars evaluated, as well as provide a basis upon which the fruit characteristics of any new cultivars or selections in the future may be compared. Information on the fruit physicochemical properties of these cultivars will also benefit the developing fruit processing industry.

Materials and Methods

Cultivar evaluation trials of chokecherry, highbush cranberry and black currant were planted in the fall of 1994 at the University of Saskatchewan horticulture field plots in Saskatoon, Saskatchewan. A black currant trial was also established near Yorkton, Saskatchewan. The trials were arranged in a randomized complete block design with three blocks. Five plants per cultivar were planted in each block.

Fruit were harvested from one to two plants per cultivar from each block. Harvested fruit were put into plastic containers (25 x 19 x 8 cm) (Item Code PCA 9745, PCA Canada, Scarborough, ON) and placed on ice packs (Cyropak Corp., Vancouver, BC) in an insulated wooden container designed for temporary storage and transport from the field. Fruit were stored in this field cooler for up to seven hours before being frozen at -40 °C in the plastic containers.

Physicochemical analyses on the fruit were conducted on 2-3 sub-samples of fruit from each replicate from the field, depending on the analysis. Ten fruit weight was determined by weighing 10 frozen fruit. Total solids content was determined according to AOAC method 920.151 (AOAC, 1995) in which 15 g of fruit were dried in a vacuum oven at 70 °C for 24 h. The percent pit of chokecherries and highbush cranberries was measured gravimetrically by separating fruit flesh from the pit. Twenty gram samples of fruit were blended using dull blades with approximately 50 mL of 60 °C distilled water for 20 seconds. For highbush cranberry, 0.1 g of pectic enzyme (Wine Art Inc., Richmond Hill, ON) was added to the distilled water prior to blending. The blended sample was strained and the flesh remaining on the pits was manually removed. The pit weight as a percentage of the whole fruit weight was reported. The estimated percent flesh was calculated on a dry basis as the percent total solids content minus the percent pit.

Measurements of pH, soluble solids and colour were conducted on extracted juice from the fruit. For chokecherry, 50 g of fruit flesh was manually macerated with 100 mL of distilled water. The samples were then centrifuged at 8500 rpm for 10 minutes, and the resulting supernatant was utilized for pH, soluble solids, and Hunterlab colour analyses. Soluble solids readings of chokecherry juice were multiplied by a dilution factor of three to account for the effect of adding water to the fruit prior to measurement. Juice extracts of highbush cranberry were obtained by manually macerating 50 g of fruit and decanting the liquid portion. Black currant juice was obtained by placing 50 g of fruit in cheese cloth bags and manually squeezing out the juice. The pH was measured, and soluble solids content was determined by refractometer as per AOAC method 932.12 (AOAC, 1995). The colour of the juice extract was determined with a MiniScan XE colourimeter (Hunter Assoc., Reston, VA). Hunterlab L, a and b values were recorded. Juice colour was presented as the hue angle ($\tan^{-1}(b/a)$), and colour vividness by the chroma ($((a^2 + b^2)^{0.5})$). The Hunterlab L value is a measure of the lightness of the sample.

Titratable acidity was measured only for black currant fruit according to a slightly modified version of AOAC Method 920.149 (c) (AOAC, 1995). Frozen fruit (150 g) were boiled for 1 hr and then centrifuged at 8500 rpm for 10 minutes. The volume of the supernatant was made up to 1 L. The diluted supernatant was filtered through Whatman #4 filter paper and employed in the analysis as per AOAC Method 942.15 B (AOAC, 1995). Titratable acidity was calculated as percent citric acid.

Sub-sample means were used in the statistical analysis. Data were checked for normality prior to analysis. The statistical analysis was performed using the mixed procedure (Proc Mixed) of SAS Version 6.11 (SAS Institute, Cary, NC). Year and site (where applicable) were considered as random factors. Cultivar mean separation was accomplished by the Least Significant Difference (LSD) test.

Results and Discussion

Chokecherry

Fruit of the chokecherry cultivars differed significantly in their 10 fruit weights, percent pit, estimated percent flesh, pH, and in the colour characteristics of their fruit juice (Table 1). Ten fruit weights of the chokecherry cultivars ranged from 6.6 g to 9.2 g. Chokecherry fruit of Goertz and Robert had significantly greater 10 fruit weights (mean = 8.9 g) than that of Mission Red and Boughen Yellow (mean = 6.7 g). The percent pit was lowest for the fruit of Goertz (9.4%) and highest for that of Boughen Yellow (16%). The estimated percent flesh ranged from 17.2 to 23.7% and was 24% lower for fruit of Boughen Yellow than the average of the remaining cultivars which did not differ significantly from each other. Total solids content did not differ significantly among the cultivars. Fruit pH among the cultivars ranged from 3.86 to 4.25. The pH of the fruit of Garrington (4.25) was significantly greater than that of Boughen Yellow, Copper Schubert, Mission Red and Robert (mean = 3.98). Large significant differences among the cultivars existed in the hue angle of the juice extracts ranging from 34.6° to 88.2°. When ripe, chokecherry fruit can range in colour from yellow, to red, to black. Fruit of Garrington and Goertz are black, fruit of Mission Red, Copper Schubert, Robert and Lee Red are red, and that of Boughen Yellow are yellow. Chroma and L values of the fruit juice also differed among the cultivars ranging from 15.3 and 51.1, respectively for Garrington to 23.9 and 23.3, respectively, for Boughen Yellow. Fruit juice of Garrington, in particular, stood out as having colour characteristics that were distinctly different from that of the other cultivars. The fruit juice extract of Garrington had a hue angle 1.8 to 2.5 times lower (indicating a more red colour) and was 40 to 54% darker (as indicated by a significantly lower L value) than that of all the other cultivars. Fruit juice of Garrington also was significantly more vivid in colour (as indicated by a higher chroma value) than that of all the other cultivars but Goertz. The juice extract of Boughen Yellow was visually assessed as being pale yellow while that of all other cultivars ranged from pale red-pink for Lee Red, to red for Garrington. However, fruit juice of Boughen Yellow and Lee Red did not differ significantly in their hue angle. The chroma and L values indicated that the juice extracts were grayish in colour for these cultivars. It is possible that the dilution of the juice extracts prior to measurement reduced the colour intensity of the juice thereby hindering a meaningful colour assessment by the colorimeter.

The combination of a high fruit weight and low percent pit value, as for the cultivar Goertz, is desirable for processing as the amount of useable flesh would be maximized. The fruit of the cultivar Boughen Yellow, would not be very well suited for processing because of its low fruit weight, large percent pit and low estimated percent flesh. In addition, rapid browning following maceration of the fruit flesh of Boughen Yellow was observed, which would be a concern during the fruit processing of this cultivar. However, the fruit of Boughen Yellow may be suitable for wine-making.

Highbush Cranberry

Highbush cranberry cultivars differed significantly in their 10 fruit weights, percent pit, estimated percent flesh, soluble solids content, pH, and in the hue angle and L value of their fruit juice (Table 2). Ten fruit weights of the highbush cranberry cultivars ranged from 4.1 g to 7.3 g. Manitou was the largest-fruited of the cultivars evaluated and had a significantly greater 10 fruit weight than that of all other cultivars but Alaska. The percent pit and estimated percent flesh ranged from 4.6% and 14.0%, respectively, for Manitou to 8.0% to 10.9%, respectively, for Garry Pink. The percent pit of the fruit of Manitou was 32 to 43% lower than that of the other cultivars. The cultivars, Manitou and Wentworth had a significantly greater estimated percent flesh (mean = 13.6%) than the other three cultivars (mean = 11.4%). Percent total solids did not differ among the cultivars. Fruit of Manitou had the highest soluble solids content (13.3 °Brix) and that of Andrews and Garry Pink the lowest (mean = 10.6 °Brix). Fruit pH ranged from 2.89 for Manitou to 3.13 for Andrews. Highbush cranberry juice extracts ranged in hue angle from 16.0° for Alaska to 18.2° for Manitou. Although significant, these differences in colour are not large for practical purposes. L values of the fruit juice extracts ranged from 15.5 to 21.3. Fruit juice of Manitou was significantly lighter (as indicated by a higher L value) than that of all the other cultivars by 13 to 38%. The cultivars did not differ in the chroma value of their fruit juice extracts.

The high fruit weight, high percent flesh and low percent pit combined with a high soluble solids content and high acidity of the fruit of Manitou suggest that this cultivar may be the most suited of the cultivars tested for processing. This cultivar was originally selected from wild stands in Manitoba for its large fruit size (Darrow, 1975).

Black Currant

Black currant cultivars varied little in their fruit physicochemical properties. Significant differences among the cultivars only existed for fruit weight, pH and titratable acidity (Table 3). Ten fruit weight of the cultivars ranged from 7.5 g for Magnus to 12.8 g for the selection 5-23-42. Black currant selections 5-23-42, 25-23-23 and the cultivar Wellington had significantly greater 10 fruit weights (mean = 12.0 g) than that of Magnus, Topsy, Boskoop Giant and Consort (mean = 7.9 g). Black currant fruit ranged in pH from 2.85 for Wellington to 3.17 for the selection 5-24-9. The fruit of Consort, Wellington and Topsy had a significantly higher titratable acidity (mean = 3.91%) than that of the three selections (mean = 3.12%). Fruit of the black currant cultivars did not differ in their total solids and soluble solids contents, nor in the colour characteristics of their fruit juice.

The three black currant selections evaluated in this study were open-pollinated seedlings of the cultivar Öjebyn, a winter hardy, compact black currant, resistant to powdery mildew and widely grown in Scandinavia and Poland (Audette and Lareau, 1997; Brennan, 1996). These selections show promise with regards to fruit size, although the fruit were found to be slightly less acidic than a number of the other cultivars evaluated.

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Table 1. Fruit physicochemical properties of chokecherry cultivars harvested from the University of Saskatchewan (U of S), Saskatoon, SK in 1999 and 2000.

Cultivar	10 Fruit Weight (g)	% Pit (w/w)	Estimated % Flesh (dry basis)	Total Solids (%)	Soluble Solids (°Brix)	pH	Hue Angle (°)	Chroma	L
Boughen Yellow	6.9 ab[1]	16.0 d	17.2 a	33.2	16.4	3.86 a	88.2 d	15.3 a	51.1 d
Copper Schubert	7.8 abc	13.1 bc	22.9 b	35.9	18.6	4.00 ab	75.4 c	18.7 ab	44.9 bcd
Garrington	7.7 abc	13.6 c	22.6 b	36.2	18.8	4.25 c	34.6 a	23.9 c	23.3 a
Goertz	9.2 c	9.4 a	22.1 b	31.5	19.5	4.15 bc	61.5 b	20.2 bc	38.7 b
Lee Red	8.2 bc	11.7 b	22.0 b	33.7	18.8	4.08 bc	79.8 cd	17.9 ab	46.7 cd
Mission Red	6.6 a	14.3 c	23.7 b	38	18.8	4.00 ab	68.9 bc	18.9 ab	42.1 bc
Robert	8.6 c	14.5 c	23.1 b	37.6	17.3	4.05 ab	73.5 c	18.8 ab	44.7 bcd
Mean	7.9	13.2	21.9	35.2	18.3	4.06	68.8	19.1	41.6
S.E.[2]	0.48	0.90	1.03	1.36	3.21	0.079	3.57	1.28	2.92

[1] Means within a column followed by the same letter are not significantly different using LSD ($p \leq 0.05$).

[2] Standard error of the mean.

Table 2. Fruit physicochemical properties of highbush cranberry cultivars harvested from the University of Saskatchewan (U of S), Saskatoon, SK in 1999 and 2000.

Cultivar	10 Fruit Weight (g)	% Pit (w/w)	Estimated % Flesh (dry basis)	Total Solids (%)	Soluble Solids (°Brix)	pH	Hue Angle (°)	Chroma	L
Alaska	6.8 cd[1]	6.8 b	11.9 a	18.7	11.9 b	3.03 c	16.0 a	32.4	15.5 a
Andrews	4.1 a	6.8 b	11.4 a	18.1	10.2 a	3.13 d	17.6 cd	37.5	18.8 b
Garry Pink	6.3 bc	8.0 c	10.9 a	19	10.9 a	2.96 b	17.1 bc	36.5	17.7 b
Manitou	7.3 d	4.6 a	14.0 b	18.5	13.3 c	2.89 a	18.2 d	40.1	21.3 c
Wentworth	5.7 b	7.1 bc	13.2 b	20.3	12.4 b	3.04 c	16.7 ab	35.5	17.0 ab
Mean	6.0	6.6	12.3	18.9	11.7	3.01	17.1	36.4	18.0
S.E.[2]	0.25	0.77	0.62	0.44	1.46	0.025	0.55	3.95	2.06

[1] Means within a column followed by the same letter are not significantly different using LSD ($p \leq 0.05$).

[2] Standard error of the mean.

Table 3. Fruit physicochemical properties of black currant cultivars harvested from Yorkton, SK and the University of Saskatchewan (U of S), Saskatoon, SK in 1999 and 2000.

Cultivar	10 Fruit Weight (g)	Total Solids (%)	Soluble Solids (°Brix)	pH	Titratable Acidity (% Citric acid)	Hue Angle (°)	Chroma	L
25-23-23[1]	11.8 c[2]	20.4	15.1	3.04 d	3.26 ab	13	10.1	8.4
5-23-42[1]	12.8 c	22.5	16	2.99 cd	3.06 a	13.4	13.7	9.9
33381	11.0 bc	22.5	15.6	3.17 e	3.04 a	13.8	12.2	9.5
Boskoop Giant	8.1 a	21	15.1	2.96 bc	3.80 c	14	12.3	9.6
Consort	8.3 a	22.9	16.3	2.92 b	4.03 c	12	11.7	8.6
Magnus	7.5 a	23.5	16.3	3.00 cd	3.65 bc	12	12.6	9.9
Topsy	7.6 a	23.5	16.6	2.96 bc	3.79 c	12.9	11.4	9.5
Wellington	11.3 c	21.4	15.5	2.85 a	3.91 c	13.4	15.6	11.4
Willoughby	9.2 ab	22.7	16	2.99 cd	3.68 c	14.2	14.2	11.5
Mean	9.7	22.3	15.8	2.99	3.58	13.2	12.6	9.8
Standard Error	0.93	0.86	1.14	0.024	0.155	0.85	2.60	1.76

[1] Open pollinated seedlings of the black currant cultivar Öjebyn.

[2] Means within a column followed by the same letter are not significantly different using LSD ($p \leq 0.05$).

3.5. Manuscripts Submitted To The Prairie Fruit Journal

Comparative Agronomic Performance of 15 Saskatoon Cultivars At Maturity

Richard St-Pierre, Annette Zatylny and Hamish Tulloch, Department of Plant Sciences, University of Saskatchewan

Funding for this project was provided by Saskatchewan Agriculture and Food.

The cultivar performance of mature plants of 15 saskatoon cultivars grown in replicated cultivar trials at two sites (University of Saskatchewan and Moonlake, SK) were quantitatively characterized and compared over 5 years (1999-2003). The 15 cultivars included Bluff, Buffalo, Forestburg, Honeywood, JB30, Martin, Nelson, Northline, PAR 90, Parkhill, Pearson II, Pembina, Smoky, Success, and Thiessen. Data were collected on total yield, marketable yield, fruit size, evenness of ripening, ripening date and shoot growth. Of the cultivars tested, JB30, Thiessen and Martin produced both high yields (3.25-3.97 kg/plant total yield; 2.88-3.62 kg/plant marketable yield) and large fruit (13.3-13.9 mm diameter). The cultivars Pearson II, Honeywood, Smoky, Northline and Forestburg produced high yields (4.09-4.70 kg/plant total yield; 3.72-4.16 kg/plant marketable yield) and medium-sized fruit (12.1-12.4 mm in diameter). Fruit of the cultivars PAR 90, JB30, Thiessen, Success, Martin and Honeywood matured 4-7 days earlier than that of Northline, Parkhill, Buffalo and Nelson. Fruit of Pembina ripened significantly later than that of all of the other cultivars by 6-13 days. No consistent differences existed among the cultivars in their evenness of ripening. Shoot extension growth differed among the cultivars ranging from an average of 10.5 cm/yr for Parkhill to 21.4 cm/yr for JB30. Shoot growth steadily decreased each year from 1999 to 2003 approaching a plateau as the plants reached maturity.

The agronomic performance of chokecherry, pincherry, highbush cranberry and black currant cultivars evaluated in Saskatchewan

Richard St-Pierre, Annette Zatylny and Hamish Tulloch, Department of Plant Sciences, University of Saskatchewan.

Funding for this project was provided by Saskatchewan Agriculture and Food.

A number of native fruit cultivars, chokecherry, pincherry, and highbush cranberry, as well as cultivars of black currant were evaluated in replicated trials at two sites (Saskatoon and Outlook) in Saskatchewan over four years. Espenant, Garrington, Lee Red and Boughen Yellow were the highest yielding of the chokecherry cultivars (mean yield = 5.8 kg/plant at Sasktoon). The chokecherry cultivars Goertz, Lee Red, Robert, Copper Schubert, and Espenant had the largest fruit size (mean= 210 fruit/cup at Saskatoon). The pincherry cultivar Lee #4 (mean yield

= 3.1 kg/plant) yielded twice as much or more than Mary Liss or Jumping Pound. The pincherry cultivars did not differ in their fruit size. Highbush cranberry cultivars Garry Pink, Manitou and Wentworth were among those with the highest yields (mean = 2.0 kg/plant at Saskatoon). Of these, Manitou had significantly larger fruit than Wentworth and Garry Pink. In general, black currant production was low with good yields occurring in only one out of four years; this variable production was attributed to the climate. Black currant yields ranged from 0.2 kg/plant for Willoughby to 1.0 kg/plant for Consort in the first trial, and from 0.2 kg/plant for the selection 4-24-29 to 2.0 kg/plant for McGinnis Black in the second trial. Black currant cultivars with the largest fruit size included Wellington, Topsy, and three selections from the University of Saskatchewan (mean=225 fruit/cup) in the first trial, and Ben Sarek, McGinnis Black, and Ben Alder (mean=156 fruit/cup) in the second trial.

The effect of soil mulch and planting date on the survival and field establishment of saskatoon transplants

Richard St-Pierre, Annette Zatylny and Hamish Tulloch, Department of Plant Sciences, University of Saskatchewan.

Funding for this project was provided by Saskatchewan Agriculture and Food.

The effect of soil mulches and transplant date on the survival and field establishment of one-year old saskatoon plants was examined at three sites (Outlook, Keeler and Saskatoon) in Saskatchewan. Non-dormant plants were transplanted to the field once a month from late May until late September. June to September transplants were potted into 3.8 L pots and grown in a shade house to attempt to increase transplant size prior to field planting. Plants were mulched with either black plastic or wood chips following planting to the field, or left unmulched. Survival and growth measurements were recorded for 2 years following planting. At Keeler and Saskatoon, plants grown using plastic mulch had a poorer survival by 18%, but a greater plant height by an average of 52%. Plastic mulch also reduced sucker production at Saskatoon and Outlook by an average of 38%. Wood chip mulch did not enhance growth but tended to improve plant survival, although this increase was not significant relative to that of the unmulched plants. Survival was on average 43% greater for plants grown using wood chip mulch than plastic mulch. However, the wood chip mulch was found to reduce sucker production and sucker growth at Saskatoon by 68% and 40%, respectively. Delaying transplant date to increase transplant size was not beneficial. Spring transplants had the best growth and survival overall, followed by those in September.

A Note On The Impact of Heading-back Dormant Saskatoon Plants During Orchard Establishment

Richard St-Pierre and Hamish Tulloch, Department of Plant Sciences, University of Saskatchewan.

Funding for this project was provided by Saskatchewan Agriculture and Food.

For a number of years, the pruning of saskatoon transplants at the time of orchard establishment has been promoted, in the absence of any published data, and in contradiction to the scientific literature which indicates that woody plants do not benefit from radical pruning at the time of transplanting. In general, pruning dwarfs plants and can have a negative effect on economic yields early in the establishment of an orchard because woody plants require a certain amount of growth before they flower and produce fruit. This trial was established to determine the impact of heading-back on the survival, growth and yield of three saskatoon cultivars. Heading-back treatments included: no heading-back, heading-back dormant plants to 2.5 cm from the soil surface during year 2, and heading-back dormant plants to 2.5 cm from the soil surface during year 4. Two years after the first heading-back treatment was applied, a substantial reduction in plant size and branch number of the headed-back plants was observed. In general, differences between cultivars had a greater impact on the parameters measured during this study than either of the heading-back treatments that were applied. Transplant survival was unaffected any of the cultivar or heading-back treatments. The first heading-back treatment initially appeared to negatively impact some growth parameters but these effects were largely overcome by the end of the 2003 growing season. It seems that heading-back effects diminish as growing seasons pass since there was almost no differences found between plants that were headed-back during season two and those that were not headed-back at all. The second heading-back treatment resulted in reduced growth, an increase in plant height, and a slight increase in branching during the 2003 season. There is no evidence to date that these small treatment effects would have an impact on yield. Heading-back saskatoon transplants has been promoted to improve plant shape, reduce sucker production, reduce years to flowering and to increase yield. Based on results observed to date and considering the time and labour involved in conducting this practice, there is no reason to encourage growers to head-back their plants either in year 2 or year 4 of orchard establishment.

Physicochemical Properties of Fruit of 16 Saskatoon Cultivars

Annette Zatylny, Wendy Ziehl, and Richard St-Pierre, Department of Plant Sciences, University of Saskatchewan.

Funding for this project was provided by Saskatchewan Agriculture and Food.

Physicochemical properties were assessed for the fruit of 16 saskatoon cultivars harvested from 1998 to 2000 from replicated cultivar trials at two sites (Saskatoon and Moonlake, SK). The cultivars included Bluff, Buffalo, Elizabeth (at Saskatoon only), Forestburg, Honeywood, JB30, Martin, Nelson, Northline, PAR 90, Parkhill, Pearson II, Pembina, Smoky, Success, and Thiessen. Fruit weight, total solids, soluble solids, pH, titratable acidity, anthocyanin content, and colour characteristics of the fruit juice extracts were measured. Fruit of Martin, Thiessen and PAR 90 had the highest 10 fruit weights of the cultivars (mean = 16.3 g) and Success and Bluff the lowest (mean = 7.9 g). Total solids and soluble solids contents ranged from 19.9% and 14.0 °Brix, respectively for fruit of JB30 to 27.9% and 20.1 °Brix, respectively for fruit of Pembina. Fruit pH ranged from 3.65 for Nelson to 4.18 for Parkhill and Smoky. Fruit of Nelson had a titratable acidity level (0.63%) approximately twice that of Success, Pearson II, Forestburg, Honeywood, Smoky and Parkhill. The soluble solids to titratable acidity (SS/TA) ratio differed greatly among the cultivars ranging from 27 for JB30 to 55 for Parkhill. The colour characteristics of the fruit juice extracts differed among the cultivars in their chroma and L values but not in their hue angle. Anthocyanin analysis by HPLC identified four peaks, cyanidin-3-galactoside, cyanidin-3-glucoside and two unknowns. Total fruit anthocyanin content ranged from 414 μg/g for Forestburg to 852 μg/g for Nelson. Significant correlations were found between anthocyanin content and fruit pH, titratable acidity, hue angle and L value.

Physicochemical Properties of Fruit of Chokecherry, Highbush Cranberry, and Black Currant Cultivars Grown in Saskatchewan

Annette Zatylny, Wendy Ziehl, and Richard St-Pierre, Department of Plant Sciences, University of Saskatchewan.

Funding for this project was provided by Saskatchewan Agriculture and Food.

Physicochemical properties of the fruit of chokecherry, highbush cranberry, and black currant were assessed from fruit harvested from replicated cultivar trials at Saskatoon, SK and at Yorkton, SK (black currants only) in 1999 and 2000. These fruits were being evaluated by the University of Saskatchewan as potential new horticultural crops for the Canadian prairies. Fruit weight, total solids, soluble solids, pH, titratable acidity (black currant only), percent pit and estimated percent flesh (chokecherry and highbush cranberry only) were measured. Hunterlab colour characteristics of the fruit juice extracts were also analyzed. Chokecherry cultivars evaluated included Boughen Yellow, Copper Schubert, Garrington, Goertz, Lee Red, Mission Red, and Robert. Fruit of the chokecherry cultivars ranged significantly in their 10 fruit weights from 6.6-9.2g, percent pit from 9.4-16.0%, estimated percent flesh from 17.2-23.7%, and pH from 3.86-4.25. Mean total solids and soluble solids contents were 35.2% and 18.3°Brix, respectively, and did not differ among the cultivars. Chokecherry colour characteristics of their fruit juice extracts ranged significantly in their hue angle, chroma and L values from 34.6-88.2°, 15.3-23.9, and 23.3-51.1, respectively. Highbush cranberry cultivars evaluated included Alaska, Andrews, Garry Pink, Manitou, and Wentworth. Fruit of the highbush cranberry cultivars ranged significantly in their 10 fruit weights from 4.1-7.3 g, percent pit from 4.6-9.0%, estimated percent flesh from 10.9-14.0%, soluble solids content from 10.2-13.3 °Brix, and pH from 2.89-3.13. The hue angle and L values of the fruit juice extracts of the highbush cranberry cultivars ranged significantly from 16.0-18.2°, and 15.5-21.3, respectively. Mean total solids content and L values were 18.9% and 18.0, respectively; both measurements did not differ significantly among the cultivars. Black currant cultivars evaluated included Boskoop Giant, Consort, Magnus, Topsy, Wellington, Willoughby, and three selections from the University of Saskatchewan. Fruit of the black currant cultivars differed only in their 10 fruit weight, pH and titratable acidity which ranged from 7.5-12.8 g, 2.85-3.04, and 3.04-4.03, respectively. Mean total solids and soluble solids contents of black currant fruit were 22.3% and 15.8 °Brix, respectively. Black currant fruit juice extracts had a mean hue angle, chroma and L values of

13.2°, 12.6 and 9.8, respectively.

Effects Of Explant Juvenility, *In Vitro* Etiolation And Subculture Number And Length On *Ex Vitro* Rooting Of Micropropagated Saskatoons

Richard St-Pierre and Xiu-Li Shen, Department of Plant Sciences, University of Saskatchewan.

Funding for this project was provided by Saskatchewan Agriculture and Food.

Successful micro-propagation of saskatoons is limited by the problem of unsuccessful rooting. *In vitro* rooting has yielded erratic results and plants are difficult to establish in soil or an artificial medium. The objective of this study was to improve the rooting of micro-propagated saskatoons by using an *ex vitro* method. The effects of explant juvenility, *in vitro* etiolation and subculture number and length on *ex vitro* rooting were tested and possible mechanisms of these effects were examined. Shoot tips taken from the saskatoon cultivars Smoky and Thiessen with differing maturity states (juvenile vs. mature) were initiated, proliferated on a modified MS medium, and then rooted under *ex vitro* conditions after every four weeks in culture. Etiolation was applied to some cultures at the beginning of each subculture for two weeks. The percentage of plantlets rooted, the mean number of roots/plantlet and the mean length of roots/plantlet were all greater for plantlets derived from juvenile growth tissues. The rooting percentage was 64% for plantlets from juvenile source tissues, which was significantly higher than the rooting percentage (48%) for plantlets from mature source tissues. Etiolation also increased rooting in regard to the parameters measured. Etiolated plantlets rooted with a higher percentage (61%) compared to non-etiolated plantlets (51%). The combination of both explant juvenility and etiolation had an additive effect on rooting. Etiolated plantlets from juvenile source tissues produced the highest mean number of roots/plantlet (3.7) and the highest mean length of roots/plantlet (2.7 cm). The rooting percentage increased with time following rooting, from 33% at 10 days, to 66% at 20 days, and to 70% at 30 days. Plantlets of the cultivar Smoky rooted with a higher percentage (60%) than plantlets of the cultivar Thiessen (52%). Decapitation reduced rooting in both juvenile and mature source tissues. Decapitation caused more than a 25% reduction in the percentage of plantlets rooted for juvenile source tissues and an almost 40% reduction in the percentage of plantlets rooted for mature source tissues. Exogenous application of IBA partially overcome the inhibitory effect of decapitation and increased rooting from 41% to 60% in decapitated plantlets. IBA did not increase root formation in non-decapitated plantlets. There was a progressive increase in rooting with increasing number and length of subcultures. The percentage of plantlets rooted was 30% for the first subculture, 48% for the second, 65% for the third, and 68% for the fourth subculture. The stimulatory effect of explant juvenility and *in vitro* etiolation persisted in the first four subcultures. Longer subculture period also increased rooting. Plantlets derived from 6-week long subcultures rooted better than those from 4-week long subcultures (rooting percentages of 71% and 65% respectively). Higher endogenous levels of auxins, or higher auxin to cytokinin ratios associated with juvenile source tissues and *in vitro* etiolation, lowered auxin levels caused by decapitation, and reduced cytokinin levels, or increased auxin to cytokinin ratios resulting from longer or more subculture periods may be responsible for these results. Quantitative analyses of growth regulator levels, mainly auxins and cytokinins, or isolation and identification of rooting cofactors and rooting inhibitors in micro-cuttings, may further support these hypotheses. In general, the results of this study indicated that using explants from juvenile source tissues, applying etiolation *in vitro* and using more and longer subcultures would improve ex vitro rooting of micro-propagated saskatoons.

4. PERSONNEL

R. St-Pierre - 100%
H. Tulloch - 100%

5. EQUIPMENT

Rented: tractor, stereomicroscope, microcomputer, printer and scanner.

6. PROJECT DEVELOPED MATERIALS

Manuscripts Submitted To Refereed Journals

(copies of manuscripts incorporated into reports above)

Manuscripts Submitted To The Prairie Fruit Journal

(copies of manuscripts incorporated into reports above)

7. PROJECT PHOTOS

Inserted in report where used.

8. ACKNOWLEDGEMENT

All manuscripts contain an acknowledgement of support from ADF.

10. ICAR DATA ENTRY - this project has not been entered into the ICAR database. This was not considered relevant as the current contract was very short-term (October 2003 through March 2004) and was associated with the termination of an SRP Program which has never been required to be entered into the ICAR database, and which has been made up of numerous diverse projects.